AD-A119 704 CALSPAN CORP BUFFALO NY FLIGHT RESEARCH DEPT F/G 1/2
EQUIVALENT SYSTEM VERIFICATION AND EVALUATION OF AUGMENTATION E--ETC(U)
SEP 81 R E SMITH, J HODGKINSON, R C SNYDER F33615-78-C-3602
UNCLASSIFIED CALSPAN-6241-F-3-VOL-2 AFWAL-TR-81-3116-VOL-2 NL

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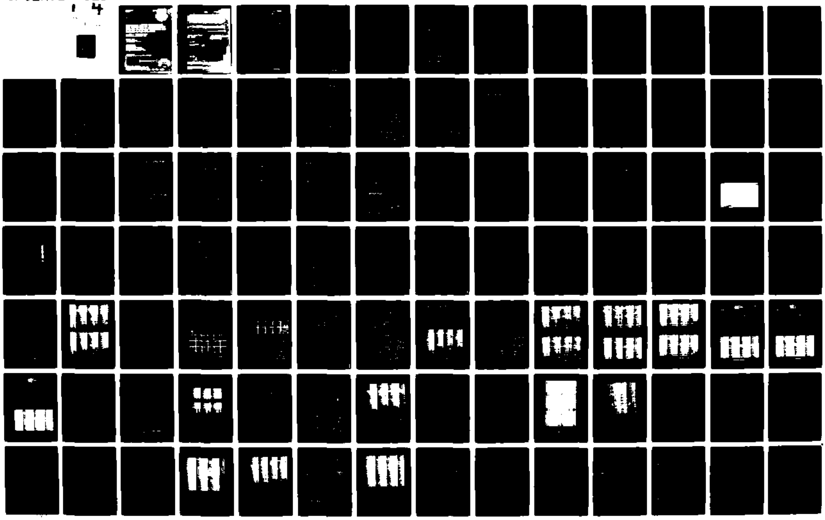

AD A119704

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFWAL-TR-81-3116	2. GOVT ACCESSION NO. AD-A229 704	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) EQUIVALENT SYSTEM VERIFICATION AND EVALUATION OF AUGMENTATION EFFECTS ON FIGHTER APPROACH AND LANDING FLYING QUALITIES VOLUME II - PROGRAM PLAN, TEST DATA AND ANALYSIS		5. TYPE OF REPORT & PERIOD COVERED FINAL REPORT July 1978 - July 1981 6. PERFORMING ORG. REPORT NUMBER 6241-F-3
7. AUTHOR(s) Rogers E. Smith, Calspan John Hodgkinson, MCAIR Richard C. Snyder, MCAIR		8. CONTRACT OR GRANT NUMBER(s) F33615-78-C-3602
9. PERFORMING ORGANIZATION NAME AND ADDRESS Calspan Corp., P.O. Box 400, Buffalo, NY 14225 McDonnell Aircraft Company McDonnell Douglas Corp., P.O. Box 516 St. Louis, MO 63166		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Program Element 62201 F 24030519
11. CONTROLLING OFFICE NAME AND ADDRESS Strike Aircraft Test Directorate Naval Air Test Center NAS Patuxent River, MD 20620		12. REPORT DATE September 1981 13. NUMBER OF PAGES 362
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Flight Dynamics Laboratory (AFWAL/FIGC) Air Force Wright Aeronautical Laboratories Wright-Patterson AFB, OH 45433		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Equivalent System Verification	Highly Augmented Aircraft
Approach and Landing Flying Qualities	Frequency Response
In-Flight Simulation	Mismatch
NT-33 Variable Stability Aircraft	Pilot Compensation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An approach and landing evaluation program was performed using the AFWAL/Calspan NT-33 variable stability aircraft to test the suitability of representing aircraft with complex flight control systems by an equivalent simplified system.

An evaluation of the equivalent systems includes effects of time delay, correlations with Pilot Ratings and comparison of frequency response characteristics for both high order and low order configurations. The analytical

descriptions of the configurations have been plotted in Bode diagrams with the corresponding step time histories. The effects of gain parameters on the matching of equivalent systems are presented.

A fast Fourier Transform method has been applied to flight time histories for analysis in the frequency response mode. The resulting response characteristics also serve as a check on the predicted responses as defined by the analytical descriptions programmed in the NT-33.

The equivalent systems data have been evaluated with the Neal and Smith closed-loop analysis technique. For the longitudinal evaluations, the validity of the equivalent system approach for evaluation of the flying qualities of complex aircraft was generally verified. The data for the lateral equivalent system evaluations were inconclusive.

FOREWORD

This report was prepared for the United States Navy and Air Force by McDonnell Aircraft Company, St. Louis, Missouri with McDonnell-Douglas Independent Research and Development funding. The Air Force Wright Aeronautical Laboratories (AFWAL) task number 24030519 "Military Flying Qualities Research" was under Project Number 2403, "Stability and Control of Aerospace Vehicles."

The report describes the results of analyses of an inflight evaluation program designed to verify the equivalent system concept and to explore the effects of control system dynamics on fighter approach and landing flying qualities.

The in-flight evaluation program reported by Calspan Corporation, Buffalo, NY was performed by the Flight Research Branch of Calspan under sponsorship of the Naval Air Test Center, NAS Patuxent River, Maryland and the Flight Dynamics Laboratory, Wright-Patterson AFB, OH, working through a Calspan contract with FDL. This work was part of Project 6241-F, NT-33 Task 3 and utilized the FDL/Calspan NT-33 variable stability aircraft. Mr. Jack Barry was the Program Manager for FDL; his assistance deserves special acknowledgement.

Completion of the in-flight program was dependent on the contributions of individuals from the McDonnell-Douglas Corporation, Navy, Air Force and Calspan. LCdr John Padgett of NATC served as Test Director; without his enthusiastic support in this capacity and his truly professional contributions as an evaluation pilot, this program would not have been possible. The engineering assistance of Mr. Bill McNamara and Mr. Tom Galloway of NATC and Mr. Tom Black of AFFDL is also acknowledged. In addition, the interest and support of Mr. Ralph A'Harrah of NAVAIR during the program was appreciated.

This report represents the combined efforts of several individuals from the aforementioned organizations. The authors wish to acknowledge the contributions of Mr. K. A. Johnston of MCAIR.

The authors also wish to express their thanks to Mr. David Bischoff, NADC for his review of the report. Mr. D. J. Moorhouse, and Mr. R. J. Woodcock, AFWAL, made many constructive changes during their very thorough review.

The time period covered by the analysis of the in-flight data extends from August 1978 through May 1981. The report was submitted by the authors in July 1981.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Concluded)

LIST OF SYMBOLS AND ABBREVIATIONS

Symbols

F_{AS}, F_{LAT}	Roll control stick force, positive right (lb)
F_{ES}, F_{LONG}	Pitch control stick force, positive aft (lb)
I_x	Moment of inertia about body x axis (slug-ft^2)
I_y	Moment of inertia about body y axis (slug-ft^2)
I_z	Moment of inertia about body z axis (slug-ft^2)
I_{x_z}	Product of inertia in body axis (slug-ft^2)
$K_{\dot{\theta}}$	Steady-state gain of constant speed $\dot{\theta}/F_{ES}$ transfer function
$K_{\dot{\phi}}$	Steady-state gain of $\dot{\phi}/F_{AS}$ transfer function
L_{α}	$\approx 1/T_{\theta_2}$
L_{δ_a}	Rolling acceleration commanded by the ailerons about x body axis (rad/sec^2 per deg)
$L'_{F_{AS}}$	Rolling acceleration commanded by stick force about pseudo x principal axis (rad/sec^2 per deg) $= (1 - I_{x_z}^2/I_x I_z)^{-1}(L_{F_{AS}} + \frac{I_{x_z}}{I_x} N_{F_{AS}})$
$M_{F_{ES}}$	$\frac{1}{I_x}\frac{\partial M}{\partial F_{ES}}$ body axis dimensional pitching moment derivative (rad/sec^2 per lb)
$N'_{F_{AS}}$	Yawing acceleration commanded by the ailerons about pseudo z principal axis (rad/sec^2 per lb) $= (1 - I_{x_z}^2/I_x I_z)^{-1}(N_{F_{AS}} + \frac{I_{x_z}}{I_x} L_{F_{AS}})$
n_z	Incremental normal acceleration at c.g., positive for pull up (g's or ft/sec^2)
n_z/α	Steady-state normal acceleration per angle of attack (g's/rad or ft/sec^2/rad)
P	Body axis roll rate (deg/sec or rad/sec)
P_{ss}	Steady-state roll rate per lb of lateral stick force (deg/sec per lb)

LIST OF SYMBOLS AND ABBREVIATIONS (Continued)

Symbols

q	Body axis pitch rate (deg/sec or rad/sec)
q_{ss}	Steady-state pitch rate per lb of pitch stick force (deg/sec per lb)
s	Laplace operator (1/sec)
α	Angle of attack (deg/or rad)
δ_{AS}	Roll control stick motion, positive right (inches)
δ_{ES}	Pitch control stick motion, positive aft (inches)
ζ_{SP}	Short period damping ratio
ζ_{ph}	Phugoid damping ratio
ζ_e	Equivalent damping ratio
θ	Pitch attitude (deg or rad)
$\lambda_{N,D}$	Filter breakpoint frequencies (rad/sec)
τ	Time delay constant, $e^{-\tau s}$ (sec)
τ_R	Roll mode time constant (sec)
τ_{Re}	Equivalent roll mode time constant (sec)
T_{θ_2}	Airframe lead time constant in constant speed θ/F_{ES} transfer function (sec)
ω_{R_e}	Equivalent natural frequency (rad/sec)
ω_{SP}	Undamped natural frequency of short period mode (rad/sec)
ω_{ph}	Undamped natural frequency of phugoid mode (rad/sec)
$(\dot{\ })$	Rate of change of ( ) with time (1/sec)

Abbreviations

AFWAL	Air Force Wright Aeronautical Laboratories
CAS	Control Augmentation System

LIST OF SYMBOLS AND ABBREVIATIONS (Concluded)

Abbreviations

deg	Degree
ESP	Equivalent Systems Program
ES	Equivalent System
FDL	Flight Dynamics Laboratory
HOS	High Order System
in	Inch
gals	Gallons
KIAS	Knots, Indicated Airspeed
lb	Pound
LOS	Low Order System
MCAIR	McDonnell Aircraft Company
ms	Millisecs
NADC	Naval Air Development Center
NATC	Naval Air Test Center
PIO	Pilot Induced Oscillation
PR	Pilot Rating
rad	Radian
SPR(SP)	Safety Pilot Rating
LAHOS	Landing Approach Higher Order System
ft	Feet

SECTION I

INTRODUCTION AND PURPOSE

The demand for increased fighter capability in combination with the demonstrated reliability of modern electronic systems has led to the evolution of more complex flight control systems. Although not a problem in itself, this additional complexity typically introduces significant control system dynamics which can potentially alter the flying qualities of the aircraft dramatically. Modern fighter aircraft such as the F-16, YF-17 and F-18A are examples of designs which utilize full-authority augmentation systems; in each case the response to pilot inputs is "higher order" and cannot be described solely by classical aircraft response parameters such as those presented in MIL-F-8785C (Reference 1).

Research programs utilizing the AFWAL/Calspan NT-33 (References 2, 3, and 4) have clearly demonstrated the need for special flying qualities criteria or specifications for today's aircraft with significant control system dynamics. One suggested approach which shows promise is to reduce the overall response transfer function of the complex highly augmented aircraft to a form which is similar to that of the classic unaugmented aircraft (e.g., References 5, 6, and 7). The new transfer functions are equivalent systems which represent the significant characteristics of the overall aircraft responses. MIL-F-8785C requires *definition* of equivalent systems for all axes. The modal specification requirements are then to be applied to the appropriate parameters of the equivalent systems, rather than to any one mode of the actual aircraft dynamics. Guidance on defining equivalent systems and applying the specification requirements is presented in the new backup report (Reference 8).

The application of an equivalent system approach to flying qualities specifications has been suggested in several reports but has recently been studied intensively by McDonnell Aircraft Company (MCAIR); for example, see References 6 and 7. The exploratory research program to verify the applicability of the equivalent system approach which is documented in the following sections was, in fact, largely motivated by McDonnell personnel.

The purpose of this research program may be summarized as follows:

- To test the suitability of representing aircraft with complex flight control systems by an equivalent system: a simplified model of classic order plus a transport time delay,

- To study the effects of transport time delay on longitudinal approach and landing flying qualities,

- To obtain lateral approach and landing flying qualities data for aircraft with significant additional control system dynamics in the form of transport time delays and lag filters.

It is important to realize that this program was exploratory in nature; the time available to conduct the program was very limited. Every effort was made to evaluate a wide variety of longitudinal and lateral approach and landing characteristics in the time available rather than concentrate on one particular aspect of equivalent systems or flying qualities data applicable to highly augmented aircraft. The reported data should, therefore, be viewed in this light.

An evaluation of the equivalent systems includes comparison of frequency response characteristics, in addition to pilot ratings and comments, for both high-order and low-order configurations. The effects of gain modifications and time delay in control system dynamics are investigated as applicable to equivalent systems. The analytical description of each configuration has been presented in Bode plots with the corresponding step time histories. A Fast Fourier Transform method has been applied to flight time history data for analysis in the frequency response mode. The resulting response characteristics also serve as a check on the predicted responses as defined by the analytical descriptions programmed in the NT-33. Also, the Neal and Smith closed-loop analysis technique has been applied to the flight data to check for correlation with the pilot ratings of the configurations.

SECTION II

EQUIVALENT SYSTEMS

The concept of equivalent systems has been discussed and published for a number of years (for example References 2, 3, 5, 6, and 7). This concept involves approximating high order mathematical models of aircraft dynamics with low-order models. These low-order models are equivalent in the sense that they produce a dynamic response to the pilot's input which is reasonably close to the high-order response.

One appeal of these low order responses is the reduced number of parameters which must be discussed in analysis and design. For example, modern flight control system mathematical models of fiftieth order are sometimes encountered. The large number of parameters needed to define such systems exactly far exceeds the number which can be comprehended in design.

Another appeal is that the flying qualities Military Specification, MIL-F-8785, has in recent versions specified modal parameters based on classical low-order dynamic responses. For example, a fourth order model is assumed for the pitch response to control. This approach was adopted in the Specification because the majority of substantiating research data were gathered with aircraft for which a low-order response was clearly an adequate approximation. The high-order modes were clearly well separated in frequency from those modes of interest in piloted control. Until recent years such an assumption fit common practice very well.

One immediate drawback of the equivalent system approach as a specification method is the necessity to quantify a "reasonably close" match between the high order and low order equivalent response. Official adoption of equivalent systems for MIL-F-8785C has increased this necessity. Therefore, this experiment evaluated the flying qualities of high order systems, and of their low order equivalents. The variable stability capabilities of the USAF/Calspan NT-33 aircraft allowed simulation of systems of appropriate order. By relating differences in pilot comments and ratings to analytical differences between the high and low order responses, allowable levels of mismatch were to be defined. Further, cases were chosen so that mismatches fell in different frequency ranges.

In recent years, the equivalent system approach for specification or assessment of flying qualities for highly augmented aircraft has been studied extensively by MCAIR (see, for example, References 6 and 7). It has been learned that the great majority of augmented responses can be approximated by quasi-classical forms of the longitudinal, lateral and directional dynamics. Equivalent systems have to date been used by MCAIR to demonstrate compliance with every classical modal requirement stated in MIL-F-8785C, i.e., the phugoid, longitudinal short period, dutch roll, roll, and spiral modes.

Three methods have been used by various investigators to obtain low order representations of the high order dynamics:

1. Selecting a subset of the high order roots for evaluation - sometimes called the "dominant root" approach.

2. Matching time histories.

3. Matching Bode frequency-response plots.

The latter approach was used for this study.

The short-term, or short-period, pitch rate response is selected as the appropriate dominant response for the task, in this case, approach and landing. This choice is reasonable since other characteristics such as the long-term response and the flight path stability and response were essentially constant and satisfactory for all the evaluations in this experiment.

The low order system is of the form:

$$\frac{\dot{\theta}}{F_{ES}} = K_{\theta} \cdot \frac{(T_{\theta_e} s + 1)e^{-\tau s}}{\left(\frac{s^2}{\omega_e^2} + \frac{2\zeta_e}{\omega_e} s + 1\right)}$$

where T_{θ_e} is an equivalent T_{θ_2} ($\simeq 1/L_\alpha$) (held fixed in matching procedure at airframe value of T_{θ_2}, if possible; when this numerator term is freed, i.e., included in the match process, an equivalent L_{θ_e} is obtained which describes the pitch response only. It is freed only to improve the analytical match.)

ω_e is an equivalent short period natural frequency

ζ_e is an equivalent short period damping ratio

The roll rate response is selected as the appropriate dominant lateral response for the approach and landing task. For the cases under evaluation, the spiral mode was considered to be approximately neutral and the Dutch roll poles approximately cancelled the roll rate transfer function zeros. Thus, the low order system can be of the form:

$$\frac{\dot{\phi}}{F_{AS}} = K_{\dot{\phi}} \frac{e^{-\tau s}}{(\tau_{Re} s + 1)}$$

where τ_{Re} is an equivalent roll mode time constant

τ is a time constant of the control system time delay to allow proper matching of phase contributions of high frequency control system elements.

Normally, the sideslip-to-rudder control response is used to obtain an estimate of the equivalent dutch roll characteristics. This is particularly necessary when the dutch roll is nearly cancelled in the lateral (bank angle) response to lateral control. In this experiment, however, the dutch roll characteristics though not constant, never affected the task, ratings, or pilot comments. Therefore, the analysis was restricted to the $\dot{\phi}/F_{AS}$ response.

In both axes, a time delay, $e^{-\tau s}$, is used as a way of approximating the high frequency phase lags introduced by actuation, sensors, and compensation. (Note that MIL-F-8785C limits phase lag due to flight control system effects at the short period natural frequency. A time delay has a phase lag, at a frequency of radians/second of

$$\text{Phase Lag} = 57.3\ \tau\omega\ \text{(degrees)}$$

where τ is the delay in seconds.) Introduction of this delay term in the matching process was necessary to get good matches.

The matching of the high order transfer function of the highly augmented aircraft to this low order model is performed using a special digital computer program. For aircraft like the YF-17 and F-18A, the complete transfer function can, in some situations, be as high as 50th order. The quality of the match is measured by a cost, or mismatch, function which is formed by summing the squared errors in gain and phase between the low and high order transfer functions at a number of frequency values. For the longitudinal matches, the cost function is:

$$\text{"Cost"} = \Sigma\{ [\Delta\text{Gain (dB)}]^2 + .017\ [\Delta(\text{Phase (deg)}]^2\}$$

The weighting factor of .017 assigns the same significance to 1 dB of gain mismatch as to approximately 8 degrees of phase mismatch.

For the matches in this report a frequency range between .1 and 10 rad/sec was selected for the matching procedure.

The approach to application of equivalent systems has been outlined, but questions are raised. For example, how close to the equivalent must a representation be? The degree of allowable mismatch between the high order system and its low order equivalent needs to be defined. The frequency range for equivalence evaluation should be defined. Also, in determining longitudinal equivalents, it has been found that freeing the short period pitch numerator in the matching process is one way to reduce the mismatch (noted in definition of low order system). The resulting equivalent system is valid only for the pitch degree of freedom. It also has been discovered that small mismatches could not be obtained for some configurations, and these configurations had poor flying qualities. However, such configurations also have equivalent system parameters which predict poor flying qualities, as shown in Reference 10.

Past experience with flying qualities analysis of the systems studied has indicated that mismatch is not a strong concern. Nevertheless, this correspondence between mismatch and pilot rating has raised the question as to whether low-order-appearing responses are a prerequisite to good control qualities.

Another parameter choice available for modeling the low order equivalent is time delay. High order dynamics often produce large lags at high frequencies. These lags cannot be approximated by simple low order equivalent modal parameters and pilots describe these responses as delayed. Therefore, the equivalent systems often include an equivalent time delay, or transport delay, to approximate the phase lag. High order dynamics which reduce to a low order system having a large delay value are prone to pilot induced oscillations and loss of control in demanding tasks. However, the equivalent pure delay only approximates the lagged but smooth initial response onset of the high order continuous system. The question arises as to whether it simulates the high order response with sufficient accuracy. Also, digital flight control systems introduce actual transport delay in the response to control inputs. The question of accuracy need not arise for this case, since the equivalent delay term is an exact representation. In any event, the question of how much delay will degrade pilot rating needs to be answered.

Because of these questions, and the need for equivalent systems correlations to bridge between researchers and specification writers and users, experimental data were needed. In this experiment, pilot ratings for both high and low order systems are collected with the intent of gaining insight into the major questions of mismatch. The major objective of the Equivalent Systems Program, initially reported in References 9 and 15, was to determine whether analytically determined equivalent systems possess similar flying qualities to their high order counterparts.

SECTION III

LONGITUDINAL EXPERIMENT DETAILS

1. <u>OBJECTIVES</u> - The objectives of this phase of the program were:

   o To test the equivalency, through pilot evaluations in the AFWAL/Calspan NT-33 in-flight simulator, of a variety of high and low order systems.

   o To obtain data on the effects of transport time delays - such as occur in digital flight control systems - on longitudinal flying qualities.

Special exact time delay circuits were incorporated into the NT-33 variable stability system to allow replication of the desired low order equivalent systems and to study the effects of time delay on approach and landing flying qualities.

For this experiment, the high order systems were drawn from two sources:

a. F-18A In-Flight Evaluation Program (Reference 12)

   - Since the major features of the F-18A digital flight control system were replicated in the NT-33 for the F-18A approach and landing evaluations, the high order models from the F-18A evaluation program were utilized.

   - No additional time delay was included in these models for the equivalent system program; therefore, the high order systems are configurations representative of the F-18A as simulated in the NT-33. Hence, the models used are representative high order systems for advanced fighter aircraft.

b. Landing Approach Higher Order System Program, "LAHOS" (Reference 4)

   - For efficiency, selected high order systems from the LAHOS program were utilized as evaluation configurations for the equivalent system program.

   - Force commands instead of the LAHOS's position commands were, however, used in this equivalent system program. Equivalent systems for LAHOS in Reference 11 therefore included a small equivalent delay to account for the feel system dynamics. A small actual delay to approximate this feel system was used in the equivalent system program.

The characteristics of the longitudinal configurations evaluated in this experiment are described in the following subsections. In general, the intent was to explore equivalent systems for a variety of flying qualities levels, including cases with $1/T_{\theta_e}$ free (numerator term is freed to improve match process).

2. LONGITUDINAL MECHANIZATION - The evaluation configurations were mechanized using the NT-33 variable stability system, special electronic circuits, and special digital time delay circuits. A detailed description of the NT-33 in-flight simulator is contained in Reference 13, while a complete description of the digital time delay circuits and the F-18A simulation is given in Reference 12.

The longitudinal mechanization block diagram is shown in Figure 1. This figure applies to all configurations except for two advanced fighter aircraft configurations. In certain cases, special mechanization strategies were necessary to achieve specific equivalent systems as described in Subsection III-4. For each configuration, other than the advanced fighter higher order systems (HOS-1, 2), the complete constant speed pitch rate transfer function can be constructed using the block diagram and the data summary sheets in Section VI. Transfer functions for the advanced fighter aircraft are presented in the next subsection (further details also are available in Reference 11).

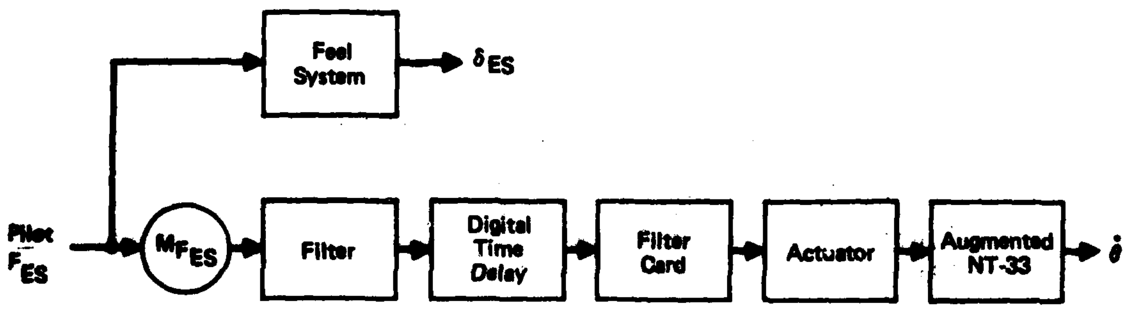


Figure 1. Longitudinal Pitch Rate Block Diagram

Block diagram elements are:

o FILTER:

$$\frac{(\frac{1}{\lambda_N})\ s + 1}{(\frac{1}{\lambda_D})\ s + 1} \text{ or } \frac{1}{(\frac{1}{\lambda_D})\ s + 1}$$

o DIGITAL TIME DELAY:

$$e^{-\tau s}$$

- **FILTER CARD:**

I

$$\frac{\frac{s^2}{2.3^2} + \frac{2(.6)}{2.3}s + 1}{\frac{s^2}{3.5^2} + \frac{2(.6)}{3.5}s + 1}$$

II

$$\frac{\frac{s^2}{2.3^2} + \frac{2(.6)}{2.3}s + 1}{\frac{s^2}{4.0^2} + \frac{2(.75)}{4.0}s + 1}$$

III

$$\frac{\frac{s^2}{2.3^2} + \frac{2(.6)}{2.3}s + 1}{\frac{s^2}{5.3^2} + \frac{2(.7)}{5.3}s + 1}$$

IV

$$\frac{1}{\left(\frac{s^2}{16^2} + \frac{2(.94)}{16}s + 1\right)\left(\frac{s^2}{16^2} + \frac{2(.38)}{16}s + 1\right)}$$

V

$$\frac{1}{\frac{s^2}{12^2} + \frac{2(.7)}{12}s + 1}$$

- **ACTUATOR:**

$$\frac{1}{\frac{s^2}{75^2} + \frac{2(.7)}{75}s + 1}$$

- **AUGMENTED NT-33:** (Constant Speed)

$$\frac{s + \frac{1}{T_{\theta_2}}}{s^2 + 2\,\zeta_{SP}\,\omega_{SP}\,s + \omega_{SP}^2}$$

- **GAIN:** $M_{F_{ES}}$ is given for each configuration in the data summary sheets in Section VI, Table 5

- **FEEL SYSTEM:**

$$\frac{.14}{\frac{s^2}{25^2} + \frac{2(.7)}{25}s + 1}\ \text{(in/lb)}$$

NOTE: (1) Essentially zero breakout and friction forces were present.

(2) Considering pilot force as the primary input to the actuator, the feel system dynamics did not enter into the response as they did in the LAHOS experiment. Here, the feel system only drove the control stick.

3. EVALUATION CONFIGURATIONS - The evaluation configurations are presented in Table 1. For the table, the constant speed form of the $\dot{\theta}/F_{ES}$ transfer function is used; ζ, ω are the damping ratio and frequency of the equivalent system (ES) or classic short period form as noted in the remarks. In the table, the configurations are separated into logical groups of equivalent system or time delay variation data sets. Appendix D shows calculated time and frequency response comparisons based on the table descriptions. Since the experiment was exploratory, variations in characteristics, such as gain and time delay, were sometimes made "on-line" resulting in several versions of a configuration.

Some configurations required modification of the NT-33 pitch numerator root, and others required an ω_e value beyond the normal range of the closed-loop variable stability system. Special mechanization strategies were then necessary to replicate the desired $\dot{\theta}/F_{ES}$ transfer functions. Details of these cases are described in subsection III-6. For clarity, only the final configuration characteristics are listed. Exact configuration transfer functions can be constructed using the block diagram (Figure 1) and the data summary sheets in Section VI. The transfer functions of the advanced fighter aircraft are given in Table 2. An example complete transfer function is included at the end of this subsection.

For the transfer functions, the short form notation is used: $(S+10) \equiv (10)$, $(S^2+2\zeta\omega s+\omega^2) \equiv [\zeta;\omega]$ etc.

The data presented in Tables 1 and 2 are for the nominal 135 KIAS approach flight condition. Information for extrapolation to the flare flight condition is given in Subsection III-5. Long term characteristics for Table 1 configurations are summarized in Subsection III-6.

Complete sets of the full longitudinal transfer functions for the advanced fighter can be found in Reference 11. HOS-1 and -2 are cases 3 and 1 in Reference 12.

As an example of the construction of the complete constant speed $\frac{\dot{\theta}}{F_{ES}}$ transfer function, consider Configuration P3 (refer to data summary sheets in Section VI and Figure 1).

TABLE 1

LONGITUDINAL EVALUATION CONFIGURATIONS (APPROACH)

CONFIG.	ω Rad/Sec	ζ	L_α (1/Sec)	τ (Sec)	REMARKS
P1		(HOS-1)			Advanced Fighter HOS (45° Flap)
P2	1.5	1.1	0.5	.12	ES for P1, L_α Fixed
P2A	1.6	0.8	0.5	.12	P2 with gain changed (1)
P3	3.5	0.6	6.3	.07	ES for P1, L_α Free
P3A	3.5	0.6	6.3	.07	P3 with gain changed (1)
P4		(HOS-2)			Advanced Fighter HOS (30° Flap)
P4A	-	-	-	-	P4 with gain changed (1)
P5	1.9	1.4	.55	.12	ES for P4, L_α Fixed
P5A	1.9	1.4	.8	-	Modified ES for P4
P5B	1.9	1.4	.55	.12	P5 with gain changed (1)
P5C	1.9	1.4	.8	.12	Modified ES for P4
P6	5.3	0.7	12.5	.06	ES for P4, L_α Free
P7	(HOS - LAHOS CONFIG. 4-3)				Force Commands
P8	1.6	0-.8	0.8	.10	ES for P7, L_α Fixed
P9	4.0	0.75	00	-	ES for P7, L_α Free

TABLE 1 (Continued)

LONGITUDINAL EVALUATION CONFIGURATIONS (APPROACH)

CONFIG.	ω Rad/Sec	ζ	L_α (1/Sec)	τ (Sec)	REMARKS
P10	2.6	0.6	0.8	-	LAHOS 2-1, Force Commands
P10A				.05	P10 plus Feel System Delay
P10B				.10	P10 plus Time Delay
P10C				.13	P10 plus Time Delay
P10D				.20	P10 plus Time Delay
P11	(HOS - LAHOS CONFIG. 2-11)				Force Commands
P11A	-	-	-	.05	HOS P11 plus Feel System Delay
P12	2.6	0.6	0.8	.17	ES for P11, L_α Fixed
P12A					P12 with $\frac{S+2}{S+6}$ Filter Added
P12B					P12 with $\frac{S+10}{S+20}$ Filter Added
P12C					P12B with gain (1) changed
P12D					P12A with gain (1) changed
P13	(HOS - LAHOS CONFIG 4-7)				Force Commands
P13A	-	-	-	.05	P13 plus Feel System Delay
P14	2.1	1.0	0.8	.09	ES for P13, L_α Fixed

TABLE 1 (Continued)

LONGITUDINAL EVALUATION CONFIGURATIONS (APPROACH)

CONFIG.	ω Rad/Sec	ζ	L_α (1/Sec)	τ (Sec)	REMARKS
P15	(HOS - LAHOS CONFIG. 1-4)				Force Commands
P16	0.8	0.6	0.8	.16	ES for P15, L_α Fixed
P16A	0.8	0.6	0.8	.14	Modified ES for P15
P17	1.9	0.8		-	ES for P15, L_α Free

NOTE: (1) Command gain was varied for evaluation of configuration parameters on equivalency.

(2) Time delay, τ, given in table are identifier values for the configurations. Total time delays for analyses are summation of identifier time delay, equivalent delay in filters for time delay network circuit, and the surface actuators.

TABLE 2

ADVANCED FIGHTER CONSTANT SPEED PITCH TRANSFER FUNCTIONS (APPROACH)

CONFIG.	$\frac{\dot{\theta}}{F_{ES}}$ TRANSFER FUNCTION
HOS-1	$\frac{(20)(10)(5)(2.5)(1.0)(1.0)(.55)}{[.7;3.2][.9;1.1](16.4)(10.7)(6.7)(4.1)(.76)}$
HOS-2	$\frac{(20)(2.5)(1.0)(1.0)(.55)}{[.8;4.6][.9;1.0](12.3)(6.7)(.64)}$

NOTE: Actuator dynamics must be added (see Section III-2); exact transfer function gains can be determined from summary data sheets in Section VI.

For approach conditions:

$$\frac{\dot{\theta}}{F_{ES}} = M_{F_{ES}} \cdot \underbrace{e^{-.07s}}_{\text{TIME DELAY}} \cdot \underbrace{\frac{\cancel{\left(\frac{s^2}{2.3^2} + \frac{2(0.7)s}{2.3}+1\right)}}{\left(\frac{s^2}{3.5^2} + \frac{2(0.6)s}{3.5}+1\right)}}_{\text{FILTER CARD I}} \cdot \underbrace{\frac{(6.3\ s+1)}{\cancel{\left(\frac{s}{0.7}+1\right)}}}_{\text{FILTER}} \cdot \underbrace{\frac{1}{\frac{s^2}{75^2} + \frac{2(0.7)s}{75}+1}}_{\text{ACTUATOR}}$$

$$\cdot \underbrace{\frac{0.8\cancel{\left(\frac{s}{0.8}+1\right)}}{2.6^2\cancel{\left(\frac{s^2}{2.6^2} + \frac{2(0.7)s}{2.6}+1\right)}}}_{\text{AUGMENTED NT-33}}$$

Assuming that the crossed out factors approximately cancel (a reasonable assumption; they would exactly cancel in the flare - see Section III-5), the resulting transfer function is the desired equivalent system listed in Table 1 as Configuration P3.

4. LONGITUDINAL COMMAND GAINS - The original strategy for command gain selection was to keep the constant-speed, steady-state pitch rate per pound of stick force, q_{ss}, constant within a particular set of configurations; target values of q_{ss} were taken from the data sources, References 3 and 10. Values of q_{ss} are given for each configuration in the data summary sheets in Section VI; also presented are the values of "pitch control sensitivity", $M_{F_{ES}}$, for each evaluation configuration.

For the classic unaugmented aircraft, $M_{F_{ES}}$ is the high frequency gain of the $\dot{q}/F_{ES}$ transfer function and is therefore a suitable yardstick for comparison of initial response characteristics. In configurations with significant additional control system dynamics, this correlation may no longer be valid. Comparison of initial response characteristics cannot be done using $M_{F_{ES}}$. Care should therefore be taken when interpreting the effects of command gain differences.

During the course of the program, variations of command gain were made to investigate the sensitivity of equivalency to system parameters. All of these variations are included in the data summary sheets in Section VI.

5. EXTRAPOLATION OF CONFIGURATION DATA TO LANDING CONDITIONS - A given configuration was evaluated during the program at different NT-33 fuel loads or weight since several configurations were evaluated during each flight. The approach was flown at a constant angle of attack of 10 units (approximately 6 degrees true) which has the effect of holding the important dynamic characteristics approximately constant. Approach speed was therefore a function of fuel remaining.

During the flare and landing phase of the task the airspeed decreased approximately 15 knots below the approach value; angle of attack increased about 25% and was approximately constant regardless of weight. In summary, the following data applies to the approach and landing phases:

- Approach:

Nominal Speed	~ 135 KIAS
$1/T_{\theta_2}$	~ 0.8 rad/sec
n_z/α	~ 5.6 g/rad

- Flare and Landing:

(Less than 50 ft above touchdown)

Nominal Speed	~ 120 KIAS
$1/T_{\theta_2}$	~ 0.7 rad/sec
n_z/α	~ 4.4 g/rad

- Extrapolation of Configuration Data to Landing Task: Although the difference between configuration characteristics for approach as opposed to landing flight conditions is not really significant in light of the exploratory nature of this experiment, the guidelines for extrapolation of the configuration data to the landing flight conditions are presented. To be totally correct, any analysis of the data should use the flare and landing data since the landing task is the critical task (Reference 4).

For extrapolation of the data to the flare and landing conditions, the following rules apply: T_{θ_2} and q_{ss} increase about 10%; ω_{sp} decreases about 10%; ζ_{sp} is approximately constant; $M_{F_{ES}}$ decreases about 20%.

The advanced aircraft $\dot{\theta}/F_{ES}$ transfer functions for approach conditions in Table 2 when extrapolated for the landing task become:

$$\text{HOS-1} \qquad \frac{(20)(10)(5)(2.5)(1.0)(1.0)(.55)(.68)}{[.7;2.9][.8;1.0](17.2)(10.5)(6.7)(4.3)(.79)(.75)}$$

$$\text{HOS-2} \qquad \frac{(20)(2.5)(1.0)(1.0)(.55)}{[.8;3.9][.9;.9](14.3)(6.7)(.78)}$$

6. <u>SPECIAL TRANSFER FUNCTION MECHANIZATION SUMMARY</u> - Since the equivalent system concept under evaluation is based on the assumption that the pitch attitude (rate) response is the dominant response, every effort was made to replicate the desired pitch rate, constant-speed transfer functions. Two problem areas were encountered in trying to accomplish this objective:

- <u>NT-33 $1/T_{\theta_2}$ Mismatch - Normally, the numerator of the transfer function of</u> pitch to pilot control contains a root $1/T_{\theta_2}$ ($\approx L_\alpha$) which is also the bandwidth of flight path response to attitude. Since there is no independent control of lift in the NT-33 simulation, the flight path bandwidth of the NT-33 could not be varied except by changing 1-g trim angle of attack (speed).

  For those configurations requiring pitch numerator root values different than the NT-33 values (for example, Configuration P2) an appropriate lead/lag filter was used to achieve the desired pitch rate transfer function, without modifying the flight path pitch attitude bandwidth.

  The filter characteristics for each configuration are given in the data summary sheets in Section VI. Note that where the NT-33 L_α was cancelled, the flare and landing values were used.

- <u>High Equivalent Frequency</u> ω_e - For Configurations P3, P6 and P9 the requisite ω_e was beyond the capability of the NT-33 simulator in the landing approach condition. This is because high ω_{sp} is obtained using a large angle-of-attack feedback gain, which reduces loop stability. In these cases special filter cards were mechanized (Cards I, II and III) to achieve the desired overall pitch rate transfer function. The NT-33 was augmented to achieve well-calibrated short period denominator characteristics which were cancelled by the numerator term in the filter card. The denominator of the filter card had a high ω value which for control inputs became the effective ω_e. Again, the flare and landing values for ω_{sp} were used. The high ω_e values were a consequence of allowing L_α to be free to improve the analytical matches.

The complete configuration transfer functions for either the approach or the flare and landing condition can be constructed using the block diagram in Figure 1 and the data in Sections III-2 through III-5 and the data summary sheets in Section VI.

7. LONG TERM PITCH CHARACTERISTICS - For all the evaluation configurations the phugoid, or long term, response characteristics are those of the NT-33 as modified somewhat by the longitudinal feedback gains used to achieve the desired short period dynamics. For this experiment, the following values are representative. More accurate data can be found in References 4 and 12.

$$\omega_{ph} \approx .15 \quad , \quad \zeta_{ph} \approx .15$$

$$T_{\theta_1} \approx 12 \text{ sec}$$

From the flight path control viewpoint, all the evaluations were on the "front side" of the power required versus drag curve.

8. LATERAL-DIRECTIONAL CHARACTERISTICS - A "good" set of lateral-directional characteristics was selected for this phase of the equivalent systems program. Pilot commentary indicated that these characteristics were satisfactory and not a factor in the longitudinal evaluations. The specific dynamics used were those of configuration L-5.

SECTION IV

LATERAL EXPERIMENT DETAILS

1. OBJECTIVES - The main emphasis for this phase of the program was placed on gathering the first flying qualities data on the effects of control system augmentation on lateral approach and landing flying qualities. The effects of control system lag and time delay were explored using a long and short roll mode time constant.

A secondary objective was to test the equivalency of lateral high and low order systems.

As for the longitudinal phase, the high order systems were drawn from the F-18A In-Flight Evaluation Program (Reference 12). The models selected are not direct representations of the F-18A in particular, but they are representative of advanced fighter aircraft higher order lateral systems in general.

The characteristics of the lateral configurations evaluated in this experiment are described in the following subsections.

2. LATERAL MECHANIZATION - The evaluation configurations were mechanized using the NT-33 variable stability system special electronic circuits and special digital time delay circuits.

The lateral mechanization block diagram is shown in Figure 2. This figure applies to all configurations except two advanced fighter aircraft configurations. For each configuration, other than the advanced fighter higher order systems (HOS-3,4), the complete roll rate transfer function can be constructed using the block diagram and the data summary sheets in Section VI. Transfer functions for the advanced fighter aircraft are presented in the next subsection. Further details are available in Reference 12.

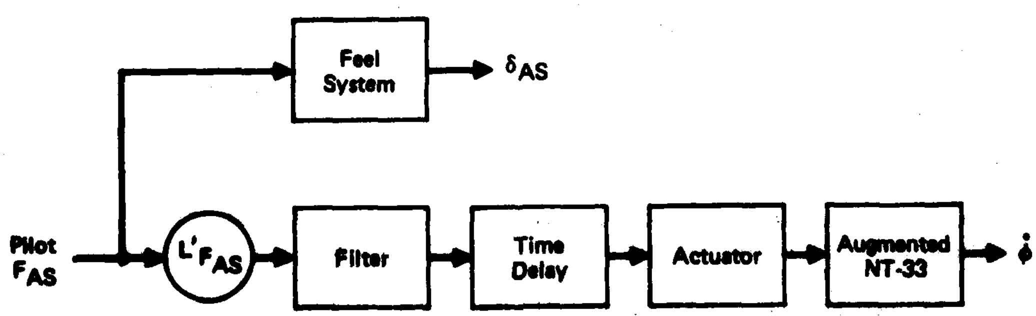


Figure 2. Lateral Roll Rate Block Diagram

Block diagram elements are:

- FILTER: $$\frac{1}{(\frac{1}{\lambda_D})\, s + 1}$$

- DIGITAL TIME DELAY: $e^{-\tau s}$

- ACTUATOR: $$\frac{1}{\frac{s^2}{60^2} + \frac{2(.7)s}{60} + 1}$$

- AUGMENTED NT-33: $$\frac{1}{(s + \frac{1}{\tau_R})}$$

  NOTE: See Section IV-6 for exact spiral and Dutch roll characteristics.

- GAIN: $L'_{F_{AS}}$ is given for each configuration in the data summary sheets in Section VI.

- FEEL SYSTEM: $$\frac{.28}{\frac{s^2}{25^2} + \frac{2(.7)s}{25} + 1} \text{ (in/lb)}$$

  NOTE: Essentially zero breakout and friction forces were present. The Dutch roll was essentially cancelled and the spiral mode was negligible.

3. <u>EVALUATION CONFIGURATIONS</u> - The evaluation configurations are presented in Table 3. Exact configuration transfer functions can be constructed using Figure 2 and the data summary sheets in Section VI. Since the experiment was exploratory, different pilots were sometimes presented with slightly different versions of a configuration. Therefore nominal values of parameters are shown to clarify grouping of configurations.

Transfer functions for the advanced fighter aircraft are given in Table 4. The shorthand transfer function notation of Table 2 is used.

The data presented in Tables 3 and 4 are for the nominal 135 KIAS approach flight condition; information for extrapolation to the flare flight condition is given in Subsection IV-5. Other lateral-directional characteristics are summarized in Subsection IV-6.

Complete sets of lateral-directional transfer functions for the advanced fighter can be found in Reference 12; HOS-3 and HOS-4 are cases 4 and 3 in Reference 12.

TABLE 3

LATERAL EVALUATION CONFIGURATIONS (APPROACH)

CONFIG	τ_R [(3)] (Sec)	τ (Sec)	λ_D (Rad/Sec)	REMARKS
L1	(HOS-3)			Advanced Fighter HOS (45° Flap)
L2	.45	.07	20	ES for L1
L3	(HOS-4)			Advanced Fighter HOS (30° Flap)
L4	.45	.05	20	ES for L3
L4A	.45	.05	20	L4 With Gain [4] Changed
L5	.40	-	20	Short Time Constant-Lag
L5A	.40	-	-	L5 Without Lag
L6	.40	-	10	Short Time Constant-Lag
L7	.40	-	5	Short Time Constant-Lag
L7A	.40	.09	5	L7 With Time Delay
L8	.40	-	2	Short Time Constant-Lag
L8A	.40	-	1	Short Time Constant-Lag
L8B	.40	-	.7	Short Time Constant-Lag
L9	.40	.09	20 [(2)]	Short Time Constant-Time Delay
L10	.40	.14	20	Short Time Constant-Time Delay
L10A	.40	.14	-	L10 Without Filter
L11	.40	.20	20	Short Time Constant-Time Delay
L11A	.40	.20	20	L11 With Gain [4] Change
L11B	.40	.20	20	L11 With Gain [4] Change
L11C	.40	.30	20	Short Time Constant-Time Delay
L11D	.40	.15	2	Short Time Constant-Lag Plus Time Delay

TABLE 3 (Continued)

LATERAL EVALUATION CONFIGURATIONS (APPROACH)

CONFIG	τ_R (3) (Sec)	τ (Sec)	λ_D (Rad/Sec)	REMARKS
L12	.85	-	20	Long Time Constant-Lag
L12A	.85	-	-	L12 Without Lag
L13	.85	-	10	Long Time Constant-Lag
L14	.85	-	5	Long Time Constant-Lag
L14A	.85	-	2	Long Time Constant-Lag
L14B	.85	-	1	Long Time Constant-Lag
L15	.85	.09	20 (2)	Long Time Constant-Time Delay
L16	.85	.14	20	Long Time Constant-Time Delay
L16A	.85	.20	20	Long Time Constant-Time Delay

NOTES: (1) Actuator dynamics must be added (see Section IV-2); exact gains for the transfer functions can be determined from summary data sheets in Section VI.

(2) Because of NT-33 lateral mechanization difficulties, a 20 rad/sec filter was typically necessary for configurations in Table 3 with time delay variations.

(3) Exact roll mode time constant values are given in Section VI.

(4) Command gain was varied to check its effect on equivalency.

(5) Time delay, τ, given in table are identifier values for the configurations. Total delay times for analyses are summation of identifier time delay, equivalent delay in filters for time delay network circuit, and the surface actuators.

TABLE 4

ADVANCED FIGHTER ROLL TRANSFER FUNCTIONS (APPROACH)

CONFIG.	p/F_{AS} TRANSFER FUNCTIONS
HOS-3	$\frac{(21)}{(32)(24)(7.5)(5)}$
HOS-4	$\frac{(21)}{[.97;23](15)(5)}$

NOTES: (1) Actuator dynamics must be added (see Section IV-2); exact gains for the transfer functions can be determined from summary data sheets in Section VI.

As an example of the construction of the complete p/F_{AS} transfer function, consider Configuration L9 (refer to data summary sheets in Section VI and Figure 2).

For approach conditions:

$$\frac{p}{F_{AS}} = L'_{F_{AS}} \cdot \underbrace{e^{-.09s}}_{\text{TIME DELAY}} \cdot \underbrace{\frac{1}{\frac{s}{20}+1}}_{\text{FILTER}} \cdot \underbrace{\frac{1}{\frac{s^2}{60^2}+\frac{2(0.7)s}{60}+1}}_{\text{ACTUATOR}} \cdot \underbrace{\frac{1}{s+\frac{1}{0.4}}}_{\text{AUGMENTED NT-33}}$$

4. <u>LATERAL COMMAND GAINS</u> - The original strategy for command gain selection was to keep the steady-state roll rate per pound of stick force, (low frequency gain) p_{ss}, constant within a particular set of configurations; target values of p_{ss} were taken from Reference 12. Values of p_{ss} are given for each configuration in the data summary in Section VI.

Also presented are the values of initial roll control sensitivity, (high frequency gain) $L'_{F_{AS}}$. As noted for the longitudinal configurations with significant control system dynamics, use of high frequency gain as an indication of initial response characteristics may not be valid.

Variations in command gain were made. These variations are in the data summary sheets in Section VI.

5. <u>EXTRAPOLATION OF CONFIGURATION DATA TO LANDING CONDITIONS</u> - The differences between the approach and landing flight conditions are summarized in Section III-5. Although in the context of this exploratory experiment the effects of these differences is not really significant, the guidelines for extrapolation of the configuration data to the critical landing task are presented. For extrapolation of the configuration data to the flare and landing conditions the following rules apply: τ_R and p_{ss} increase about 10% and $L'_{F_{AS}}$ decreases about 20%.

The advanced aircraft $\frac{p}{F_{AS}}$ transfer functions in Table 4 become:

HOS-3 $\qquad \frac{(22)}{(38)(23)(5.6)(5)}$

HOS-4 $\qquad \frac{(22)}{(30)(24)(9.2)(5)}$

6. <u>OTHER LATERAL-DIRECTIONAL CHARACTERISTICS</u> - For the advanced fighter configurations, HOS-3 and HOS-4, the $\frac{p}{F_{AS}}$ transfer functions presented in Table 4 are complete. Thus instead of the classic first-order roll rate transfer functions, these aircraft have first over fourth high order transfer functions.

For the other evaluation configurations, the augmented roll rate transfer function was intended to be of classic 1st order form. However, this ideal situation was not achieved exactly because sufficient time was not available for the necessary iterations during the calibration phase of the program.

For the approach flight condition, the spiral and Dutch roll characteristics were

$$\omega_{DR} = 1.3 \text{ rad/sec}$$

$$\omega_{DR} = 0.25$$

$$\omega_{\phi} = 1.3 \text{ rad/sec}$$

$$\zeta_{\phi} = 0.35$$

$$\tau_{s} = 15 \text{ sec}$$

The Dutch roll and spiral stability effects on the roll rate transfer function were neglected.

7. <u>LONGITUDINAL CHARACTERISTICS</u> - A "good" set of longitudinal characteristics were selected for this phase of the equivalent systems program. Pilot commentary indicated that the longitudinal flying qualities were satisfactory. The specific dynamics used were those of configuration P-10.

SECTION V

CONDUCT OF THE EVALUATION PROGRAM

1. <u>AFWAL/CALSPAN VARIABLE STABILITY NT-33 AIRCRAFT</u> - The required longitudinal and lateral configuration dynamics were mechanized using the AFWAL variable stability NT-33, operated by Calspan (Figure 3). A complete description of the operation of the NT-33 is contained in Reference 12. In the NT-33 aircraft the evaluation pilot occupies the front cockpit, while the system operator, who occupies the rear cockpit, acts as safety pilot. The stability and control characteristics about all three axes can be varied in flight by changing the settings of the fly-by-wire system gain controls in the rear cockpit. Evaluation configurations were selected by the safety pilot using the appropriate calibrated system gains; additional features, such as special filters and time delay circuits, were selected using special switches in the rear cockpit.

Figure 3. USAF/CALSPAN Variable Stability NT-33

It is important to note that the evaluation pilot cannot feel the NT-33 control surface motions caused by the demands of the fly-by-wire control system in reproducing the desired configuration response characteristics.

2. <u>CALIBRATION PROCEDURES</u> - For the majority of the configurations, standard test techniques and the digital data recorder were used to identify the simulated evaluation configuration characteristics; for the advanced fighter high order configurations, calibration procedures were considerably more complex. The details of these calibration procedures can be found in Reference 12.

This program was conducted over a very short time span. The correspondingly short time available for calibration mainly affected the lateral experiment. By necessity, fixed lateral gains were used. As discussed in Section VI, these led to variations in roll mode time constant values as aircraft weight changed. In the context of this exploratory program, these variations are not significant since the original objective was simply to simulate both a short and a long time constant. Another impact of the time constraint was that the peripheral lateral-directional characteristics (Dutch roll, spiral) could not be properly "tuned." This resulted in less than perfect turn coordination; again, the effect on the results of this program is not considered to be significant. Appendices C, D, and E contain both analytical and measured flight response data for many configurations.

3. <u>EVALUATION TASKS AND GROUND RULES</u> - Since the exact definition of the task is important to any flying qualities investigation, the details of the tasks performed during each evaluation are summarized below. These tasks, in combination, provide a solid basis for assessing the approach and landing flying qualities of an evaluation configuration.

- <u>Approach and Landing Tasks</u>:

  - 3 touch-and-go flared landings (actual touchdowns) for each evaluation.

  - First landing from a straight-in approach.

  - Second landing out of a mild sidestep maneuver (75 ft lateral offset, 50 ft high, initiated at 1/4 mile).

  - Third landing out of an aggressive sidestep maneuver (150 ft lateral offset, 100 ft high initiated at 1/2 mile).

  - 500 ft touchdown zone (importance of not abandoning task stressed).

  - Touchdown $\pm$ 10 ft of runway centerline.

- Approach airspeed + 5 kts, nominal approach angle of attack was 10 units (approximately 6 degrees). At nominal gross weight NT-33 approach speed was 135 KIAS.

o <u>Evaluation Procedure</u>:

For the evaluations performed during this program, the evaluation pilot had no prior knowledge of the configuration under consideration. He flew 3 complete approach and landing patterns for each evaluation (more, if desired) and then evaluated the flying qualities using the Cooper-Harper Rating Scale and the Pilot Comment Card reproduced in Figure 4.

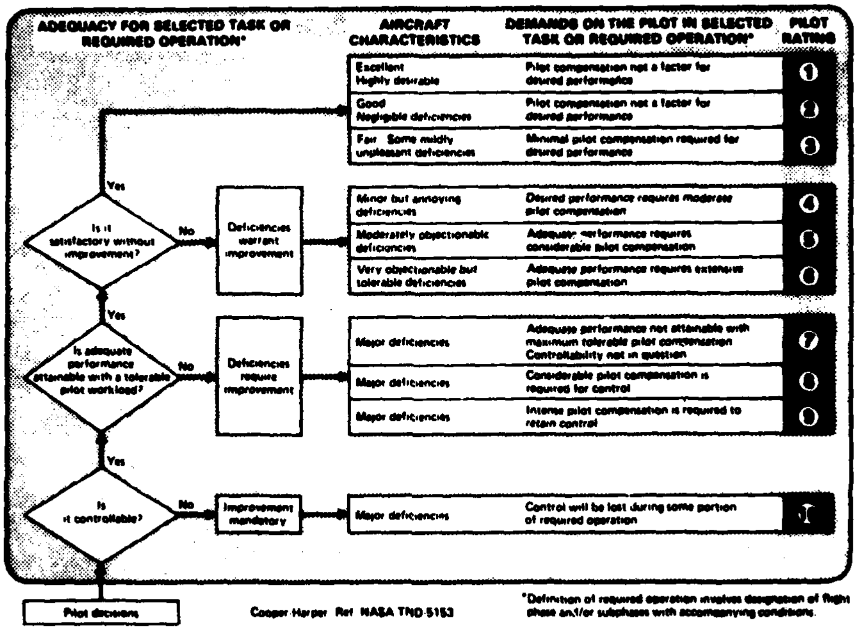


Figure 4. Cooper-Harper Rating Scale
Handling Qualities Rating Scale

<u>PILOT COMMENT CARD</u>

1. Feel characteristics: Forces, displacements satisfactory?

   - Any complaints about sensitivity?

2. Pitch attitude response to inputs <u>required to perform task</u>:

   - initial response, predictability of final response.

   - any special pilot inputs?

   - any tendency towards a PIO?

3. Velocity control: satisfactory?

4. Bank angle control:

   - satisfactory?

   - any tendency to PIO? Overcontrol?

5. Turn coordination: a problem?

6. Performance:

   - approach.

   - landing, most difficult?

7. Effects of wind/turbulence.

8. Summary comments (brief), any change in rating?

FIGURE 4b - Pilot Comment Card

The procedure was to assign a pilot rating immediately after the task was completed, make the comments using the card and finally, revise the rating if desired.

o <u>Approach Speed Considerations</u>:

For the simulation in the NT-33, the approach was flown at a nominal 10 units angle of attack. As the NT-33 weight varied during a flight, the approach speed also changed; for the nominal mid-fuel condition the approach speed in the NT-33 was 135 KIAS while the speed in the flare was 120 KIAS.

The NT-33 was calibrated to produce the correct response characteristics at these nominal speeds and angles of attack. Flying at constant angle of attack held the important dynamic characteristics approximately constant. During the flare and landing in the field landing task the airspeed decreased approximately 15 knots below the approach value.

o <u>NT-33 Approach and Landing Configuration</u>:

For the simulated landing approach evaluations, the NT-33 configuration was gear down, 30 deg flap and speed brakes out.

o <u>Wind and Turbulence Considerations</u>:

Since inclusion of wind and turbulence in a controlled fashion was beyond the limited scale of this program, flights were conducted without regard to the wind and turbulence level. In general, conditions were benign. For the longitudinal evaluations, a discrete pitch disturbance was introduced during the flare to simulate a gust upset.

4. EVALUATION DATA - The data from the program take three forms: pilot ratings, pilot comments, and digital records of task performance. Pilot rating and comment data are summarized in Section VI and Appendices A and B respectively.

5. EVALUATION PILOTS AND SUMMARY - Four evaluation pilots produced the flying qualities evaluation data summarized in this report. The evaluation pilots were:

Pilot A: LCDR J. Padgett, Navy Test Pilot and Test Director
B: LCDR S. Abbot, Navy Test Pilot
C: LCDR R. Richards, Navy Test Pilot
D: Mr. R. Scott, Test Pilot, Northrop Aircraft Co.

A total of 18 evaluation flights were flown during the two week flight program. Since the program was exploratory, every effort was made to maximize the number of evaluations. 91 evaluations (involving approximately 250 landings) were completed by the 4 pilots. The majority were done by Pilot A, the primary evaluation pilot.

SECTION VI

EVALUATION RESULTS AND OBSERVATIONS

The purpose of this section is to present the evaluation data summary sheets and briefly discuss pertinent observations.

1. LONGITUDINAL EXPERIMENT DATA - The longitudinal pilot rating data are presented in Table 5; pilot comments are summarized in Appendix A. Included in the table are the necessary configuration characteristics to allow, in conjunction with the data from Section III, construction of the pitch rate transfer function of the complete configuration.

Also included in the table, where appropriate, are the values of the MCAIR equivalent system "cost function," discussed in Section II, which compares the low-order to high-order systems as grouped in the table. The safety pilot rating (SPR) is included in the table to assist the analyst in evaluating the data. This rating was given independently by the safety pilot and is really a measure of the observed performance in the tasks

a. Effects on Pilot Rating Data of Pilot Technique - Previous flying qualities studies (References 4 and 11 for example) have indicated that, for aircraft with significant control system dynamics, small variations in pilot technique or task performance standard can result in dramatic variations in the pilot rating data. These aircraft have been appropriately described as having lurking "flying qualities cliffs". The results from this experiment also have examples of significant variations in ratings between evaluation pilots. In analyzing the data, the following information was considered.

Pilot A, who was the primary evaluation pilot for the overall program, worked very hard to maintain a constant standard of task performance despite, in some cases, the obviously poor flying qualities of a particular configuration. His continuous closed-loop flying technique was representative of typical fighter pilots. In contrast, the other main evaluation pilot, Pilot B, sometimes demonstrated very specialized pilot techniques when flying PIO prone aircraft. He is an exceptionally smooth and predictive pilot. However, when "backed into a task corner", i.e., when he was unable to use his adaptive technique, his performance was similar to that of Pilot A.

Pilot B's evaluation of Configuration P12 (Flt. 2073) exemplifies a classic problem in flying qualities evaluation of marginal highly augmented aircraft. Special piloting techniques or task conditions can allow an aircraft to "pass" the evaluation. But, when the same aircraft is exposed to normal piloting techniques and to a real-world task, it is likely to "fail". And the failure can be disastrous. During the evaluation in question, Pilot B flew the first two landings with no real difficulty

TABLE 5

LONGITUDINAL ESP DATA SUMMARY

CONF.	PILOT	FLT.	ω_{SP} (r/s) (2)	ζ_{SP}	COST FUNC-TION	FILTER λ_D	FILTER λ_N	FILTER CARD	TIME DELAY (sec) (1)	Mp_{ES} $(\frac{r/s^2}{lb})$	q_{ss}/lb $(\frac{^\circ/sec}{lb})$	FUEL (gals)	PR	SPR
P1	A	2072	(HOS - 1)		-	-	-	-	-	.03	0.8	450	2	3
	B	2070	(HOS - 1)		-	-	-	-	-	.03	0.8	400	2	3
	C	2068	(HOS - 1)		-	-	-	-	-	.03	0.8	350	3	3
P2	A	2072	1.5	1.1	136	0.7/0.5		-	.12	.03	0.6	350	2	3
P2A	C	2068	1.6	0.8	350	0.7/0.5		-	.12	.05	1.0	150	4	4
P3 (3)	A	2072	2.6	0.6	348	0.7/6.3		I	.07	.09	0.6	250	3	3
P3A	B	2070	2.6	0.6	34	0.7/6.3		I	.07	.14	0.9	250	3	3
P4	A	2071	(HOS - 2)		-	-	-	-	-	.07	1.3	100	3	3
	B	2073	(HOS - 2)		-	-	-	-	-	.07	1.3	450	4	3
	B	2073	(HOS - 2)		-	-	-	-	-	.07	1.3	100	3	3
P4A	A	2071	(HOS - 2)		-	-	-	-	-	.06	1.1	450	2	3

TABLE 5 (Continued)

LONGITUDINAL ESP DATA SUMMARY

COMP.	PILOT	FLT.	ω_{SP} (2) (r/s)	ζ_{SP}	COST FUNC-TION	FILTER λ_D	FILTER λ_N	FILTER CARD	TIME DELAY (1) (sec)	$M_{F_{ES}}$ $(\frac{r/s^2}{lb})$	q_{ss}/lb $(\frac{^\circ/sec}{lb})$	FUEL (gals)	PR	SPR
P5	A	2071	1.9	1.4	59	0.7/0.55		-	.12	.09	1.1	350	6	6
	B	2073	1.9	1.4	116	0.7/0.55		-	.12	.08	1.0	350	6	5
P5A	B	2073	1.9	1.4	3440	8.0	-	-	-	.03	0.4	100	7	6
P5B	A	2086	1.9	1.4	576	0.7/0.55		-	.12	.05	0.7	250	3	3
	B	2073	1.9	1.4	576	0.7/0.55		-	.12	.05	0.7	300	2	2
P5C	A	2086	1.9	1.4	1110	-	-	-	.12	.05	.07	350	2	3
P6 (3)	A	2071	2.6	0.7	197	0.7/12.5		III	.06	.16	1.1	250	4	5
	B	2073	2.6	0.7	197	0.7/12.5		III	.06	.16	1.1	250	4	3
P7	A	2062	2.3	1.1	-	4.0	-	-	-	.09	0.8	250	4	3
	A	2071	2.3	1.1	-	4.0	-	-	-	.09	0.8	400	2	3
	B	2063	2.3	1.1	-	4.0	-	-	-	.09	0.8	250	4	3

TABLE 5 (Continued)

LONGITUDINAL ESP DATA SUMMARY

CONF.	PILOT	FLT.	ω_{SP} (2) (r/s)	ζ_{SP}	COST FUNCTION	FILTER λ_D	FILTER λ_N	FILTER CARD	TIME DELAY (1) (sec)	$M_{F_{ES}}$ $(\frac{r/s^2}{lb})$	q_{ss}/lb $(\frac{°/sec}{lb})$	FUEL (gals)	PR	SPR
P8	A	2071	1.6	0.8	18	-	-	-	.10	.04	0.8	200	5	5
	A	2069	1.6	0.8	18	-	-	-	.10	.04	0.8	400	5	5
P9 (3)	A	2069	2.6	0.6	45	0.7	-	II	-	.14	0.9	350	3	4
P10	A	2062	2.6	0.6	-	-	-	-	-	.05	0.4	450	3	2
	B	2063	2.6	0.6	-	-	-	-	-	.05	0.4	450	2	1
	C	2068	2.6	0.6	-	-	-	-	-	.05	0.4	450	2	2
P10A	A	2069	2.6	0.6	37	-	-	-	.05	.05	0.4	150	3	2
P10B	A	2071	2.6	0.6	148	-	-	-	.10	.05	0.4	150	3	3
	B	2070	2.6	0.6	148	-	-	-	.10	.05	0.4	450	2	2
P10C	A	2072	2.6	0.6	250	-	-	-	.13	.05	0.4	200	4	5

TABLE 5 (Continued)

LONGITUDINAL ESP DATA SUMMARY

CONF.	PILOT	FLT.	ω_{SP} (r/s) (2)	ζ_{SP}	COST FUNC-TION	FILTER λ_D	FILTER λ_N	FILTER CARD	TIME DELAY (sec) (1)	$M_{F_{ES}}$ $(\frac{r/s^2}{lb})$	q_{ss}/lb $(\frac{^o/sec}{lb})$	FUEL (gals)	PR	SPR
P10D	A	2086	2.6	0.6	591	–	–	–	.20	.05	0.4	200	7	7
	B	2073	2.6	0.6	591	–	–	–	.20	.05	0.4	150	3	4
	B	2070	2.6	0.6	591	–	–	–	.20	.05	0.4	100	8	7
P11	A	2062	2.6	0.6	–	–	–	IV	–	.05	0.4	400	6	6
	B	2063	2.6	0.6	–	–	–	IV	–	.05	0.4	400	4	4
P11A	A	2086	2.6	0.6	–	–	–	IV	.05	.05	0.4	400	7	8
	A	2062	2.6	0.6	–	–	–	IV	.05	.05	0.4	150	6	7
P12	A	2069	2.6	0.6	0	–	–	–	.17	.05	0.4	450	9	9
	A	2062	2.6	0.6	0	–	–	–	.17	.05	0.4	200	7	6
	B	2073	2.6	0.6	0	–	–	–	.17	.05	0.4	400	5 (4)	9
	B	2063	2.6	0.6	0	–	–	–	.17	.05	0.4	200	7	6

TABLE 5 (Continued)

LONGITUDINAL ESP DATA SUMMARY

CONF.	PILOT	FLT.	ω_{SP} (r/s) (2)	ζ_{SP}	COST FUNC-TION	FILTER λ_D	FILTER λ_N	FILTER CARD	TIME DELAY (sec) (1)	$M_{F_{ES}}$ $(\frac{r/s^2}{lb})$	q_{ss}/lb $(\frac{^\circ/sec}{lb})$	FUEL (gals)	PR	SPR
P12A	A	2069	2.6	0.6	410	6.0/2.0	5	-	.17	.05	0.4	250	10	10
P12B	A	2072	2.6	0.6	1120	20.0/10.0		-	.17	.14	0.9	150	9	8
P12C	A	2072	2.6	0.6	133	20.0/10.0		-	.17	.07	0.5	100	5	5
P12D	A	2086	2.6	0.6	546	6.0/2.0		-	.17	.03	0.2	450	8	8
	B	2073	2.6	0.6	546	6.0/2.0		-	.17	.03	0.2	200	2	3
P13	A	2064	2.3	1.1	-	-	-	V	-	.05	0.5	450	3	3
P13A	A	2064	2.3	1.1	-	-	-	V	.05	.05	0.5	100	6	5
P14	A	2064	2.1	1.0	12	-	-	-	.09	.05	0.5	300	5	4
P15	A	2064	1.1	0.7	-	2.0	-	-	-	.04	1.5	400	8	9
	B	2070	1.1	0.7	-	2.0	-	-	-	.04	1.5	300	9	10

TABLE 5 (Concluded)

LONGITUDINAL ESP DATA SUMMARY

CONF.	PILOT	FLT.	ω_{SP} (r/s) (2)	ζ_{SP}	COST FUNC-TION	FILTER λ_D	FILTER λ_N	FILTER CARD	TIME DELAY (sec) (1)	$M_{F_{ES}}$ $(\frac{r/s^2}{lb})$	q_{ss}/lb $(\frac{°/sec}{lb})$	FUEL (gals)	PR	SPR
P16	A	2072	0.8	0.6	179	-	-	-	.16	.02	1.4	400	8	9
P16A	B	2070	0.8	0.6	232	-	-	-	.14	.02	1.6	200	5	7
	C	2068	0.8	0.6	232	-	-	-	.14	.02	1.6	250	7	8
P17	A	2064	1.9	0.8	121	0.7	-	-	-	.09	1.2	200	9	10

NOTES: (1) Time delay shown is the identifier transport time delay increments added to the NT-33 simulation. Total time delay equals identifier + .045 secs, Δt for time delay network filters plus surface actuator delays.

(2) Dynamic characteristics are for approach speeds (i.e., 6 deg angle of attach approach).

(3) Configurations P3, P6 and P9 required special mechanization in the NT-33. See Section III-6 for details.

(4) Special evaluation results. See Section VI-2 for discussion.

(5) Special evaluations with lead/lag filters added.

apparent - he was able to preplan his task and fly smoothly and predictively. On the third approach, he inadvertently allowed the sink rate to get too high, too close to the ground; urgent action was required to prevent a very hard landing. The result: a full stall, 10 feet above the runway. The pilot overcontrolled badly because of the large time delay in the pitch control system. When forced into a tight task his performance was the same as Pilot A who had rated the configuration a 9.

Unfortunately he blamed himself, not the evaluation aircraft, and after flying another approach and landing in which he was able to return to his predictive landing technique, he gave the aircraft a 5 rating.

The point of this example is not to designate Pilot B as a poor evaluation pilot - he, in fact, did an excellent job on the program - but to help the analyst interpret some of the apparent rating anomalies. Only for configurations with large time delays did Pilot B give ratings which are significantly different from those of Pilot A. It is suggested that, for the reasons just outlined, Pilot B's ratings for Flight 2073, Configurations P10D, P12 and P12D, be given special consideration. For reference, analysis of the recorded data confirmed that the selected time delay values were indeed present for these evaluations.

Note that Pilot D, in his relatively few evaluations, also exhibited a very smooth and predictive style.

b. Simulation of Equivalent Systems - The experiment, as originally planned contained precisely calculated representative values of the mismatch function so as to evaluate "good" and "poor" matches. However, the variable stability system (VSS) of the NT-33 is mechanized by response feedback. A desired set of dynamics is then achieved by calibrating the airframe dynamics as a function of VSS gains, and interpolating and extrapolating the VSS gains. Because of this mechanization, and the exploratory nature of the simulation, it was decided not to expend excess calibration flights and analysis in ensuring that the originally suggested dynamics were precisely attained. Consequently, in some cases the low order dynamics were not the optimum match (i.e., the true equivalent) of the high order dynamics. This factor did not invalidate the results.

Table 6 summarizes the equivalent system mismatch values and pilot ratings. First, the values in parentheses are analytical L_α Fixed matches to the HOS, and are not configurations in the experimental program. Next, the values of ω, ζ, $1/T_{\theta 2}$, τ, under "LOS parameter" and the gain and cost values under "flight data match" were actually flown. Thus, the cost value of 136 was the actual sum-of-squares difference between P1 and P2. Part of this difference was due to the fact that P1 has a gain of .8 and P2 a gain of .6. Finally, the gain and cost values under "optimized match" were determined analytically. The computer program minimized the mismatch by varying gain alone. Thus when the difference in gain between P1 and P2 was removed, a minimum cost of 43 was obtained by setting the gain of P2 at 96% of the gain of P1.

TABLE 6

EQUIVALENT SYSTEM PROGRAM MATCHES

CONFIG		LOS PARAMETERS				FLIGHT DATA MATCH		OPTIMIZED MATCH*		PILOT RATINGS	
HOS	LOS	ω	ζ	$1/T_{\theta_2}$	τ	GAIN	COST	GAIN	COST	A	B
P1	(P1)	(1.55)	(.937)	(.55)	(.136)	.8	-	(.93)	(36.)	2	2
	P2	1.5	1.1	.5	.165	.6	136	.96	43.	2	-
	P3**	3.5	.6	6.3	.115	.6	348	1.19	29.	3	-
	P3A**	3.5	.6	6.3	.115	.9	34	1.19	29.	-	3
P4	(P4)	(1.96)	(1.35)	(.55)	(.128)	1.3	-	(.95)	(20.)	3	3
	P5-1	1.9	1.4	.55	.165	1.1	59	.99	23.	6	-
	P5-2	1.9	1.4	.55	.165	1.0	116	.99	23.	-	6
	P6**	5.3	.7	12.5	.105	1.1	197	1.17	35.	4	4
P7	(P7)	(1.61)	(.827)	(.8)	(.116)	.8	-	(.96)	(14.)	3	4
	P8	1.6	.8	.8	.145	.8	18	.96	15.	5	-
	P9**	4.0	.75	∞	.020	.9	45	1.19	40.	3	-
P11	(P11)	(2.6)	(.60)	(.8)	(.19)	.4	-	(1.0)	(.25)	6	4
	P12	2.6	.6	.8	.215	.4	0.3	1.0	.27	8	6
P13	(P13)	(2.22)	(1.05)	(.8)	(.14)	.5	-	(.99)	(2.1)	3	-
	P14	2.1	1.0	.8	.135	.5	12	1.0	12.	5	-
P15	(P15)	(.79)	(.47)	(.8)	(.178)	1.5	-	(.86)	(156.)	8	9
	P16	.8	.6	.8	.205	1.4	179	.87	176.	8	-
	P17**	1.9	.8	∞	.020	1.2	121	1.0	49.	9	-

HOS is high order system
LOS is low order system

( ) Optimized equivalent system matched to HOS.
* Gains are matched to normalized HOS gains = 1.0.
Cost is the sum-of-squares frequency response difference between LOS and HOS; for example P2-P1 difference is 136 for no optimization performed.
Time delay includes actuator, 0.020 secs.
**L_α free equivalent system.

No correlation between mismatch value and rating differences is evident in Table 6. To try and identify differences in comments as well as ratings, a detailed examination of the comments is made, and a discussion of this comparison follows.

The data described above contain both "L_α Fixed" and "L_α Free" equivalents. In obtaining analytical matches, freeing L_α is a means to reduce the cost function and some L_α free cases were included in the experimental plan. However, the L_α free cases actually flown did not necessarily have a lower cost function than the L_α fixed cases. Though the pilot ratings in Table 6 are in closer agreement between HOS and LOS for L_α free cases, for instance configurations P3, P6 and P9, the cost function values do not show corresponding reductions.

It should be noted that *configuration* P3A is also an L_α free case and does have a reduced cost function. The gain for P3A is increased relative to P3 yet the pilot rating remains equivalent. The suggestion is that L_α free, as a means to reduce the cost function, must be combined with correct choices for other LOS parameters (i.e., gain) for best equivalency.

c. Comparing Flying Qualities of Configurations - To determine whether low order equivalent systems have similar flying qualities to their high order counterparts, Cooper-Harper ratings and the pilot comments were examined.

The pilot comments allow close comparison of flying qualities. In examining differences between pilot ratings it is necessary, however, to decide what constitutes a significant numerical rating difference.

Some contributors to pilot rating differences are:

(1) Intra-pilot variations (the pilot's own scatter, given identical tasks and aircraft dynamics);

(2) changes in task (e.g., variations in the chosen offset from the runway centerline and glide slope during the approach);

(3) changes in wind and turbulence conditions;

(4) differences in aircraft dynamics due to fuel usage.

These are roughly in order of impact upon this experiment. Normally wind and turbulence would contribute more variation. However, conditions throughout the two weeks of the experiment were generally calm and smooth. In fact, the last three items are believed to have a relatively small effect on this experiment. For convenience, the effects of all the above four causes will be lumped together as intra-pilot scatter.

Figure 5 compares Cooper-Harper ratings for the available repeated evaluations. Data from both pilots A and B are presented. As usual, we would like more data to define a hard and fast significant difference in ratings. However, the intra-pilot scatter is $\Delta PR = 2$ on the basis of repeat evaluations for several configurations, and this is consistent with other experiments. For example, the Two-Phase NT-33 simulation of Reference 16 and subsequently analyzed in Reference 11 used $\Delta PR \leq 2$ as being negligible. Therefore the criterion $\Delta PR \leq 2$ is chosen as the test of equivalence.

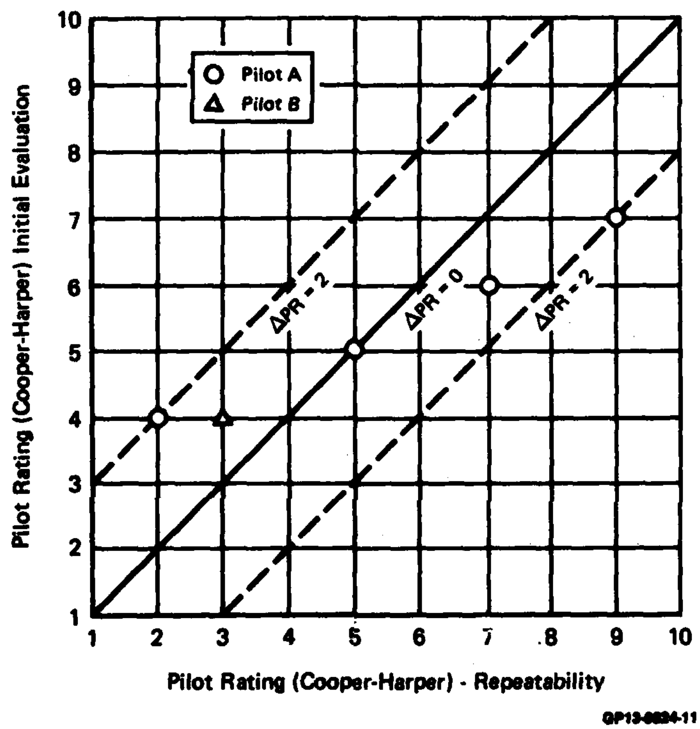
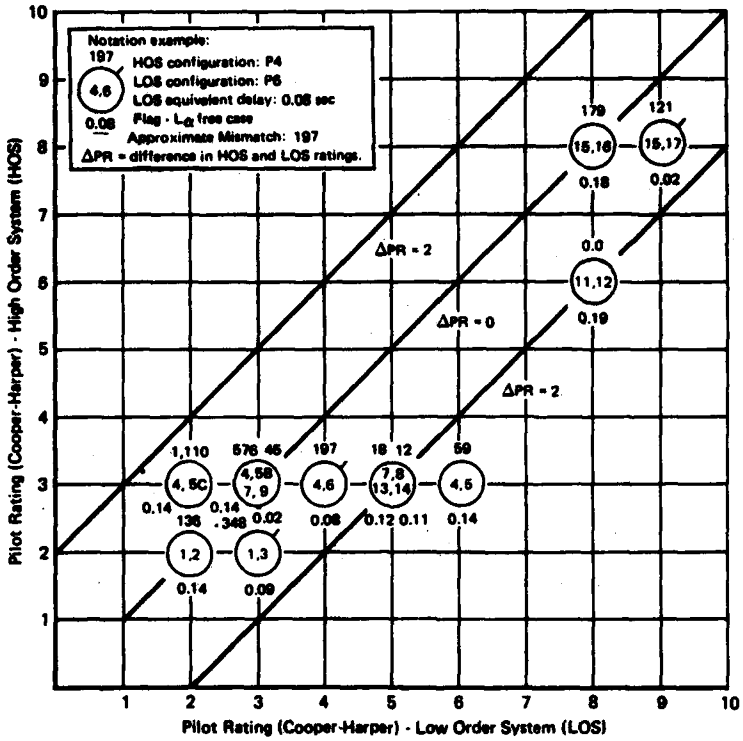
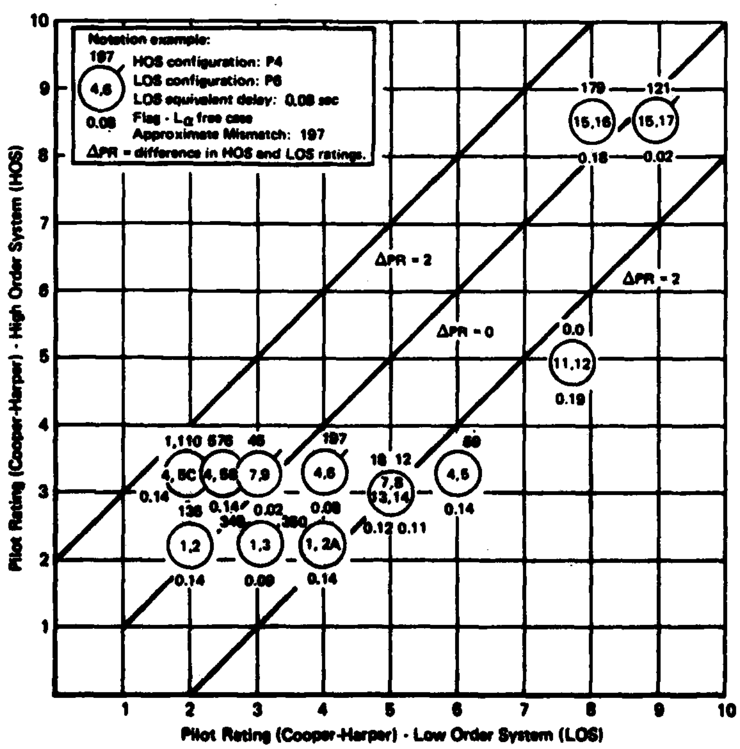


Figure 5. Pilot Rating (Cooper-Harper) - Repeatability

(1) <u>Pilot Ratings For High and Low Order Systems</u> - The pilot ratings for the high versus low order systems are shown in Figure 6. Pilot A ratings are used in Figure 6a, and in Figure 6b the mean pilot ratings (all pilots) were used. These figures summarize the flying qualities equivalence shown in the ratings and comments. The detailed comparisons are lengthy and are therefore shown in the Appendices. A typical example of frequency response comparison is shown in Figure 7. The analyses of the Appendices lead to the following general conclusions:



(a) Pilot A Ratings



(b) All Pilot's Ratings (Mean)

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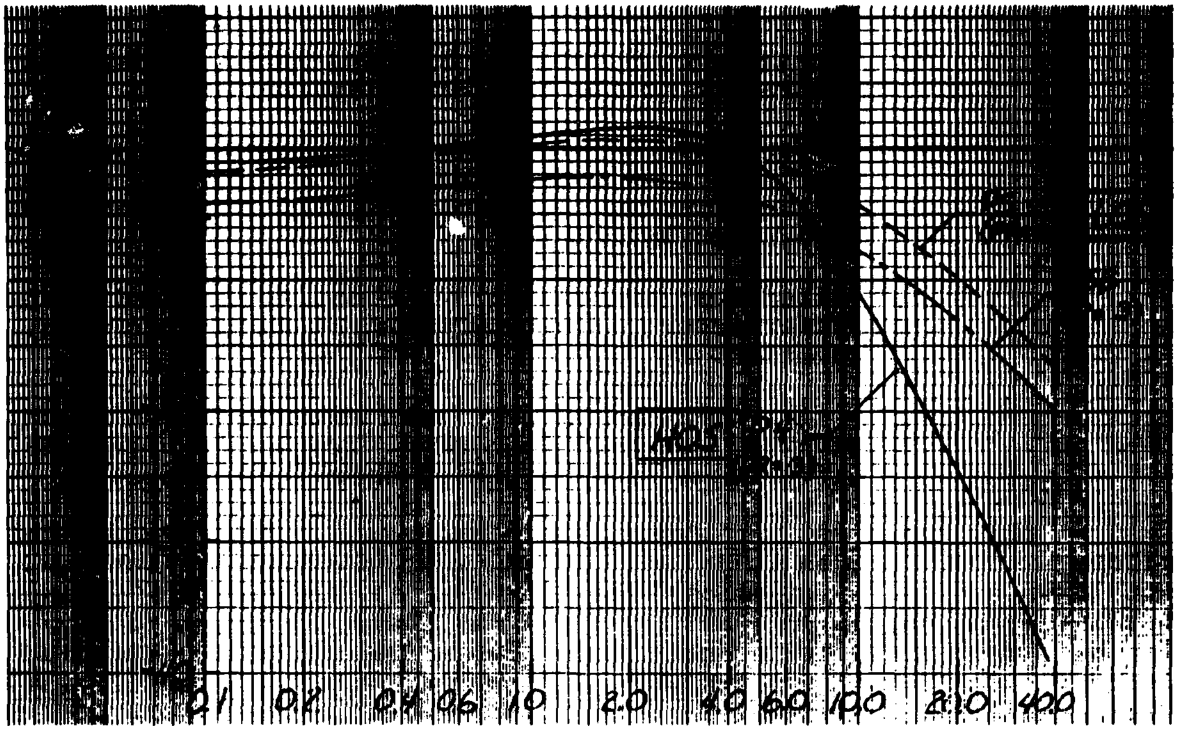
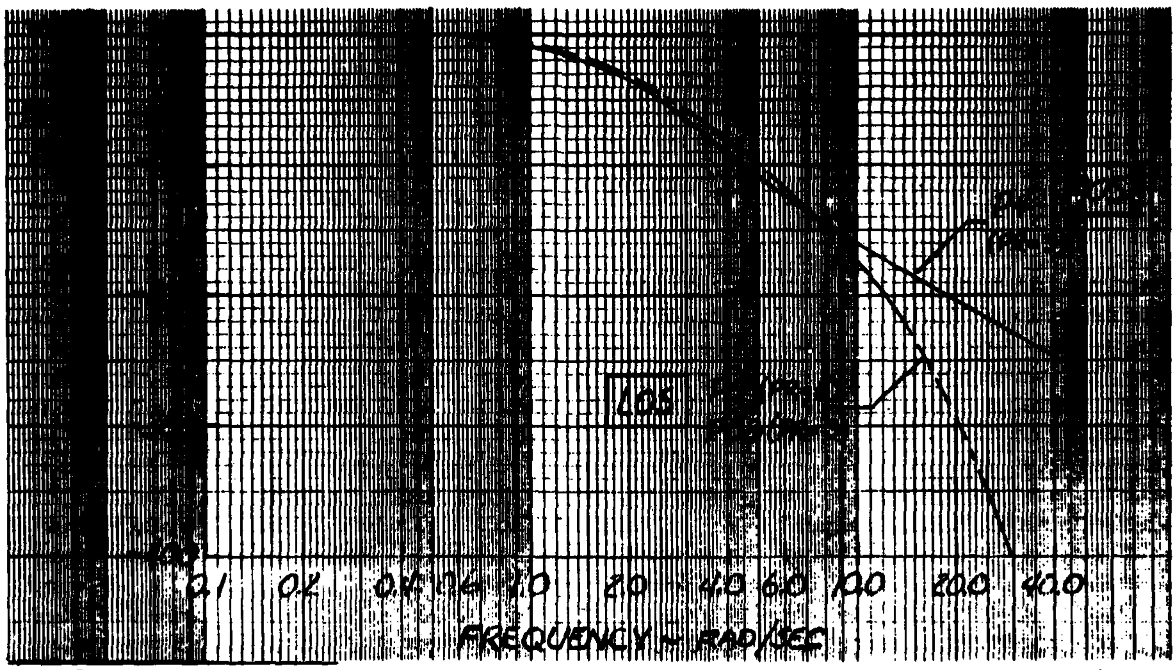
Figure 6 . Comparison of Pilot Opinion Ratings for High Order Systems and Their Low Order Equivalents





Note: Faired fourier transform data

Figure 7. Effect of High Frequency Gain Match on Pilot Rating

(a) The rating of each L_{α}-free low order system was equivalent to the high order system.

(b) Differences in rating, though generally within the pilot scatter, indicated a somewhat worse rating for the low order system than for the high order system.

(c) Differences in rating were not correlated with differences in the analytical mismatch, or cost, function.

(d) Differences in rating were sometimes, but not always, correlated with frequency response differences at frequencies above 10 rad/sec.

(2) Analysis of Rating Differences - The evaluation pilots in the ESP generally were consistent in numerical ratings, but some confusing comments (see Appendix A) between the flying qualities of the high order systems and their low order equivalents. Any rating differences were within the pilot's own rating scatter, which was representative of scatter seen in other flying qualities investigations.

Figure 6 shows that, although the rating differences were insignificant, there is an apparent consistent trend within those differences. Specifically, the ratings for the equivalent systems rarely were better than the high order ratings. Also, the scatter of points in Figure 6 indicate that Level 2 pilot ratings are the most difficult for equivalency evaluation. The following paragraphs examine possible explanations for this. The discussion is very cautious, since determination of significant trends within insignificant differences is obviously fraught with traps.

(a) General Rating Differences - Figure 8 shows mean rating differences versus mismatch value. Paradoxically, rating differences appear to be inversely proportional to mismatch. This suggests three possibilities. First, the mismatch values simply may be within normal rating scatter and trends within the scatter are meaningless. Second, the mismatch values were not large enough to be noticeable to the pilot. Third, the mismatch as presently calculated may not contain an element of the response which is noticeable to the pilot. The comparison in Figure 7 showed the pilot sensitive to mismatches at very high frequencies, and might in turn help to explain Figure 8. This idea gains some support from Figure 9; the larger rating differences occur at the larger time delays. However, P15 (HOS) and P16 (LOS) possessed a large mismatch and a large delay differences; the ratings were identical. P11 (HOS) and P12 (LOS) possessed negligible mismatch and a large delay; the rating difference was 2 points.

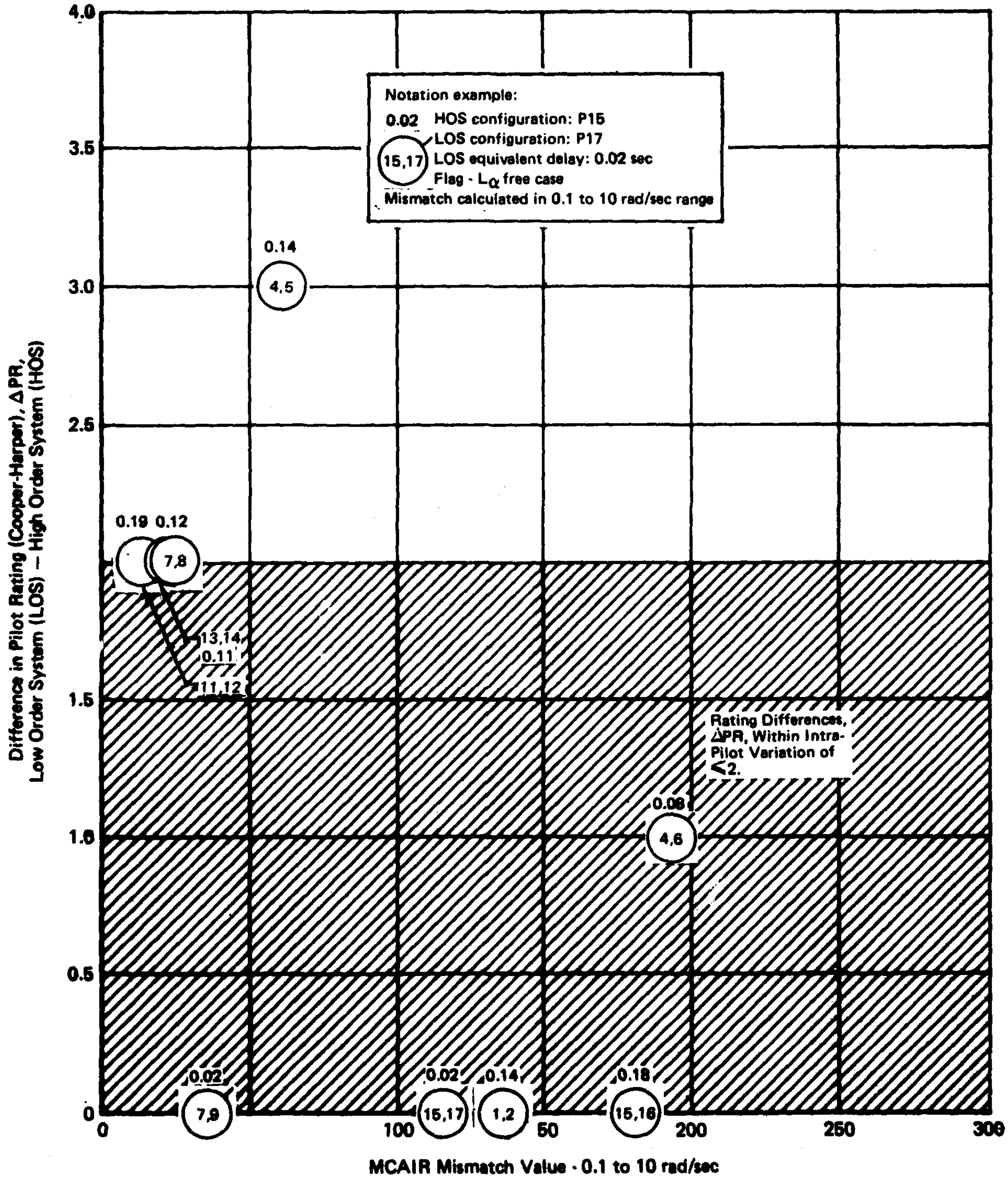


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Figure 8. Attempted Correlation Between Rating Differences and Mismatch

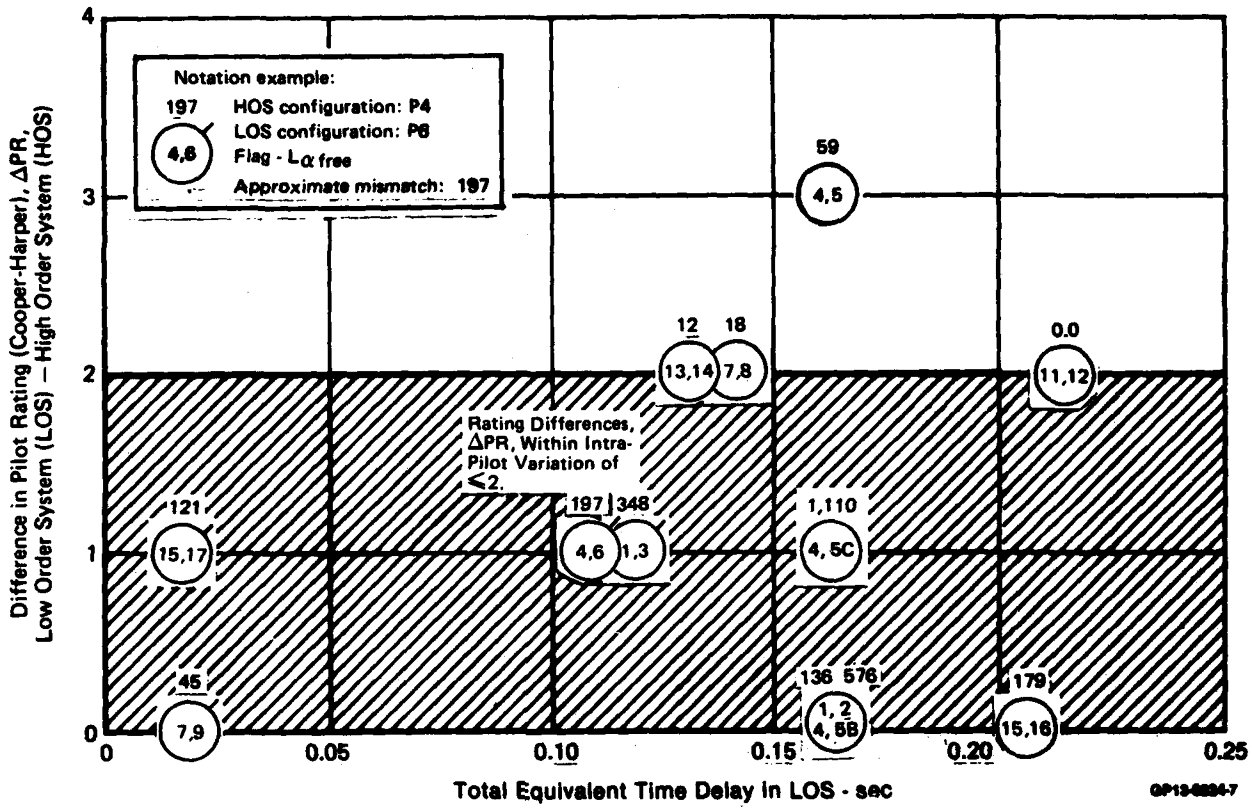

Figure 9. Attempted Correlation Between Rating Differences and Equivalent Delay

Figure 10 shows rating variation with delay for the ESP configuration P10 through P10D along with the rating degradation due to delay shown in the Landing Approach High Order Systems (LAHOS) studies of Reference 10. These previous studies used the NT-33 data of Reference 4 to show equivalent delay is a good correlating parameter for the high order systems. Configuration P10 of ESP was a set of unaugmented dynamics having Level 1 values of short period damping and frequency and was evaluated by Pilot A as having Level 1 pilot ratings. Configurations P10A through P10D were the baseline dynamics of P10 with increasing amounts of pure digital delay added. The correlation between the two sets of data is, very good. The figure suggests a value of approximately .145 seconds as the break point where increasing time delay starts significantly degrading pilot rating. Figure 11 shows the variation of pilot rating due to delay for all the high and low order systems of ESP plus the LAHOS data added for comparison. The figure shows good agreement between the two sources, LAHOS and ESP, and the data scatter is within the limits of a ΔPR < 2 presented in Figures 5 and 6. Note that the LAHOS configurations have series feel systems which is equivalent to .05 seconds of added pure time delay to the parallel feel system of the ESP configurations (i.e., LAHOS 2-11 and ESP P11).

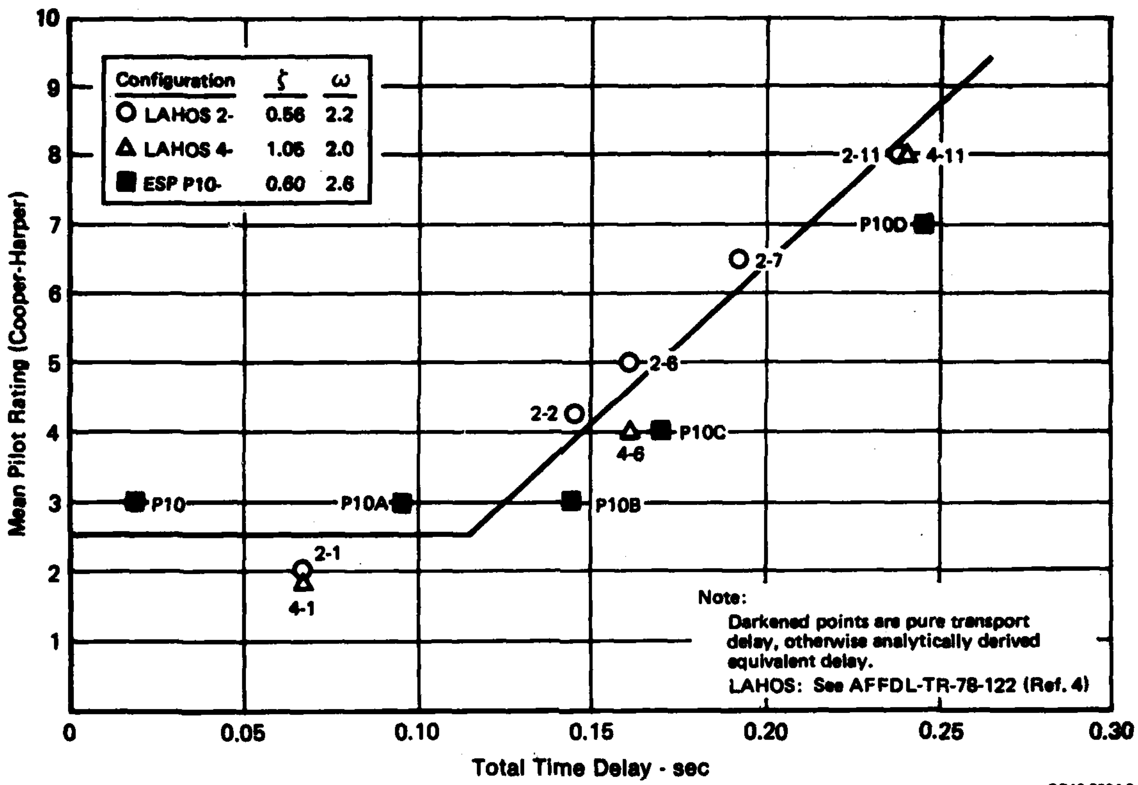

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Figure 10. Correlation of Pilot Rating with Time Delay

(b) <u>Largest Rating Difference</u> - The largest difference in ratings was the P4 vs P5 (3 vs 6 respectively, $\Delta PR = 3$). Unfortunately P4 was landed only once (rather than the usual 3 times) by Pilot A, so the rating of 3 is suspect. Pilot B flew a full evaluation of configuration P4 and awarded it ratings of 4 and 3. However in flying P4, Pilot B's rating of 3 was accompanied by a comment that he "worked hard" which is inconsistent with the rating. For P5, Pilot A "over controlled final responses, quick response" and encountered "small oscillations in flare and touchdown, small amplitude PIO", and said "Quick inputs caused PIO's". The Neal-Smith analysis of flight records in Appendix F does not shed much light on this question. Returning to open-loop correlations, though it is tempting to ascribe the piloting differences to high frequency mismatch (see the initial step time history mismatch between P4 and P5 in Figure D-3 and Figure 7). However, P1 and P2 exhibit a similar type of time history mismatch (Appendix D) but got the same ratings with no striking difference in comments.

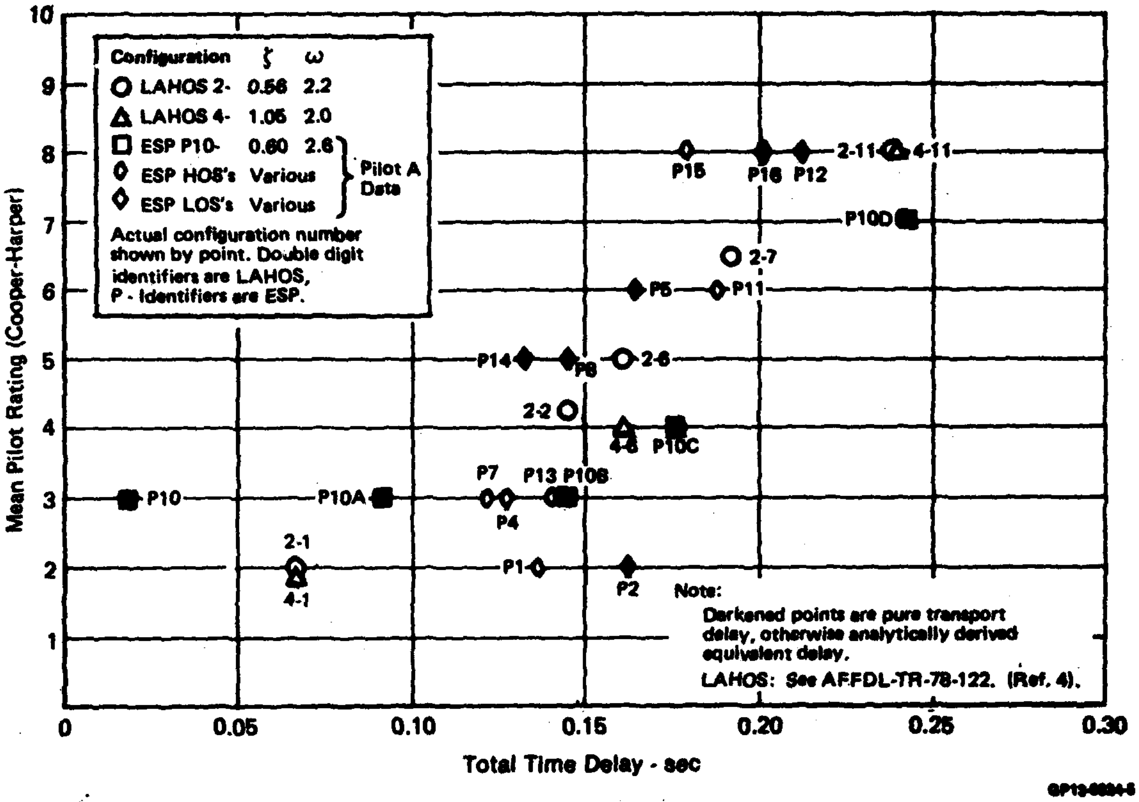


Figure 11. Comparison of Pilot Rating Variation with Time Delay for LAHOS and ESP

Configuration P5 has the most abrupt initial response (following the delay) of the longitudinal data. During the experiment, Pilot A explored this abruptness by flying this configuration again, but with a reduced gain (*P5B*) (see Appendix C, Figure C-2 and Figure 7). This change reduced the initial response slope and matched high frequency gain (ω = 5 to 10 rad/sec) more closely. The rating improved to 3, the same as the HOS P4. This suggests that gains for equivalent systems with large delays should match high frequency, not low frequency gain. This is related to the piloting problems noted by DiFrance (Reference 2). However, the pilot comments are confusing. For example, the pilot did not mention heavy control forces in P5B even though they were undoubtedly heavier than P5, which he said had "slightly heavy" forces but a quick response."

He mentioned (for P5B) "Slight hesitation, tendency to over control," "had to put input in and wait," and "could over control nose in flare-minor problem," with the rating of 3.

All of this possibly points to a high frequency piloting phenomenon. Again, this is *not* conclusive - there are inconsistent elements in the comments and it is possible that the results are simply on the extreme of normal rating scatter.

2. DISCUSSION OF LONGITUDINAL RESULTS - A review of the equivalency data shows that rather large mismatches proved insignificant to the pilot. For example, previous work had used a value of 10 as an arbitrary measure of an acceptable fit. The criterion was the visual appearance of the match when observed on a Bode plot. Though this criterion was rooted in instinct rather than science, the unnoticed mismatches of a hundred or so, which resulted from data comparisons subsequent to the pilot's evaluations, demand some explanation. Reference 14 extends a theory which explains this insensitivity using the previous NT-33 data of Neal and Smith and the LAHOS results (Reference 3 and 10).

Reference 14 develops frequency response envelopes of allowable mismatch. These envelopes were constructed by observing which types of high order dynamics in the Neal-Smith and LAHOS experiments caused a degradation in rating when compared with low order dynamics (for example, Figure 12). The low order dynamics in the present ESP contained actual time delays, which were not present in the Neal-Smith and LAHOS low order systems. However, the envelopes provide one way of examining the mismatches in ESP.

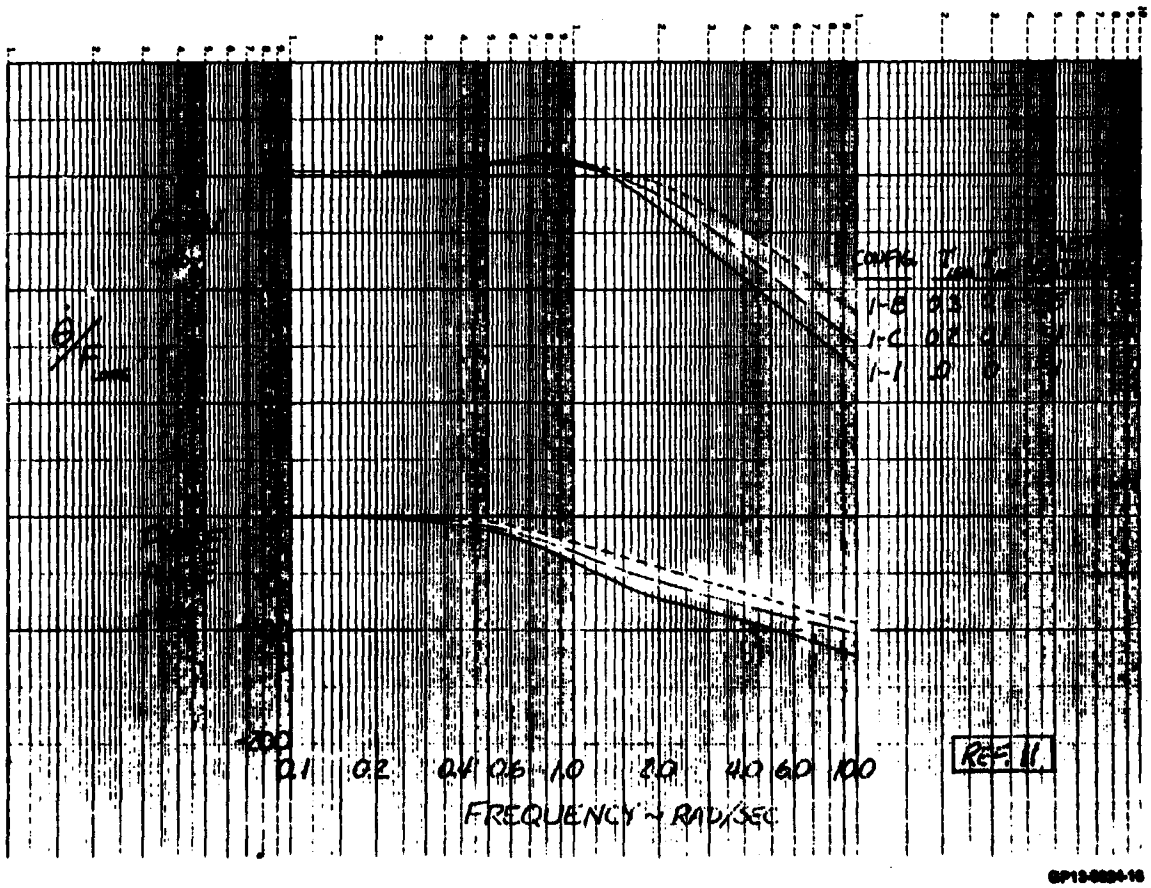


Figure 12. Effects of Added Dynamics on Frequency Response and Pilot Rating

Figures 13a through 13f compare the mismatches of the high and low order systems with the envelopes. In Figure 13 the larger violations of the envelopes tend to be accompanied by larger pilot rating differences. This trend is not true in Figures 13b and 13f. In terms of frequency responses, it is likely that the large phase lags at very high frequencies (>10 rad/sec) due to delays, or the higher gain of the equivalent system at high frequencies, are affecting the rating. The obvious next step is to examine mismatches beyond 10 rad/sec. This might mean a closer examination of any variable stability system contribution to the dynamics. In terms of time responses, the differences between initial responses (clearly evident in the step responses of Appendix D) may be noticeable to the pilot.

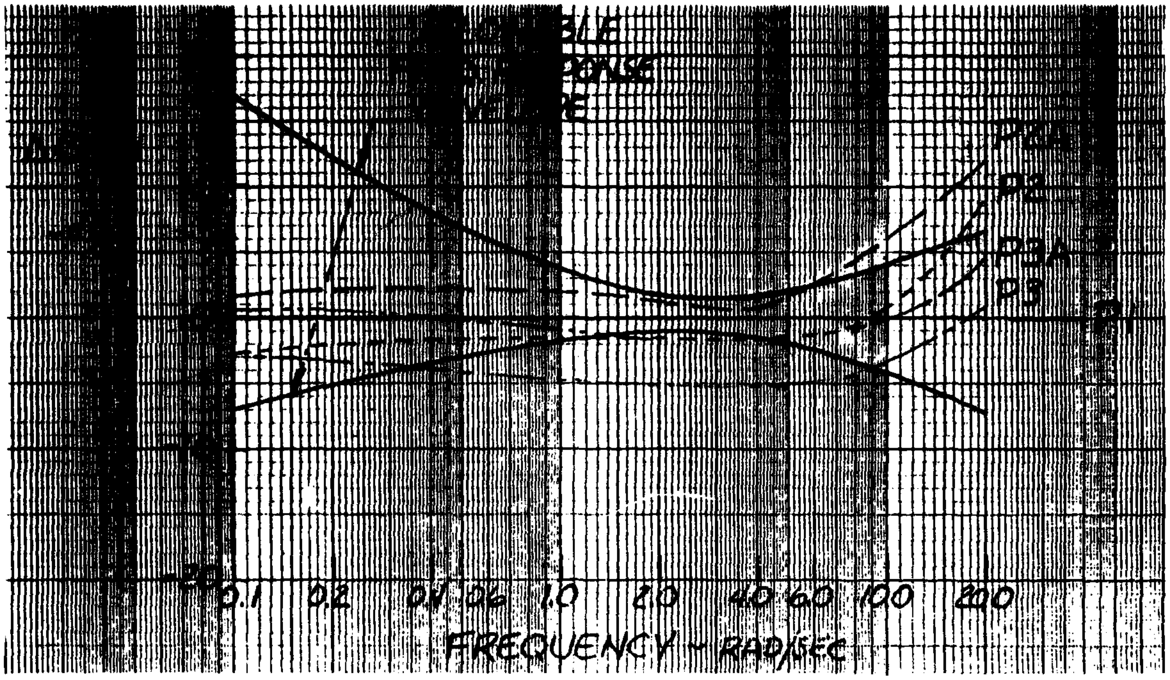
The envelopes were developed to examine differences in dynamic response shape, without taking account of gain differences. Since gain is a factor in the data of Figure 13, the envelopes appear to be a promising tool for evaluation of significant differences.

a. Gain Effects - As a starting point in this program and consideration of minimum cost, the equivalent system steady-state gain was selected to keep the constant speed pitch rate step response the same as that of the high order system. In most cases, this strategy worked fairly well; however, there is evidence that a more careful study of the question of gain is required.

Configuration P5, the equivalent system for P4, was a close match for $\omega \leq 5$ rad/sec but was downrated because of high pitch sensitivity and the "equivalency" was poor. When the steady-state gain was reduced, as in Configuration P5B, the shape of the frequency response was different with only a localized match in the area of 8 rad/sec. However, for P5B an equivalency in both pilot rating and comments was achieved with P4.

Just what "gain" is important is not clear. Preliminary evidence would indicate that the high frequency gain, i.e., higher than the 10 rad/sec cut off in the matching process, is important. It is this gain which essentially determines the initial response characteristics.

b. Special Filter Effects - A very quick look was attempted during the program (see Configurations P12A through D) into the effectiveness of special lead/lag filters which change the control system transfer function phase significantly in a particular frequency range. The intent was to shed some light on the controversy surrounding the use of the MIL-F-8785C control system requirement (Para. 3.5.3) which is based on phase angle at a particular frequency.



Pilot Rating	Config	ω_{sp}	ζ	L_α	τ	Remarks
2	P1	–	–	–	–	HOS-1
2	P2	1.5	1.1	0.5	0.12	ES for P1, L_α Fixed
4	P2A	1.6	0.8	0.5	0.12	P2 with Gain Changed
3	P3	2.6	0.6	6.3	0.07	ES for P1, L_α Free
3	P3A	2.6	0.6	6.3	0.07	P3 with Gain Changed

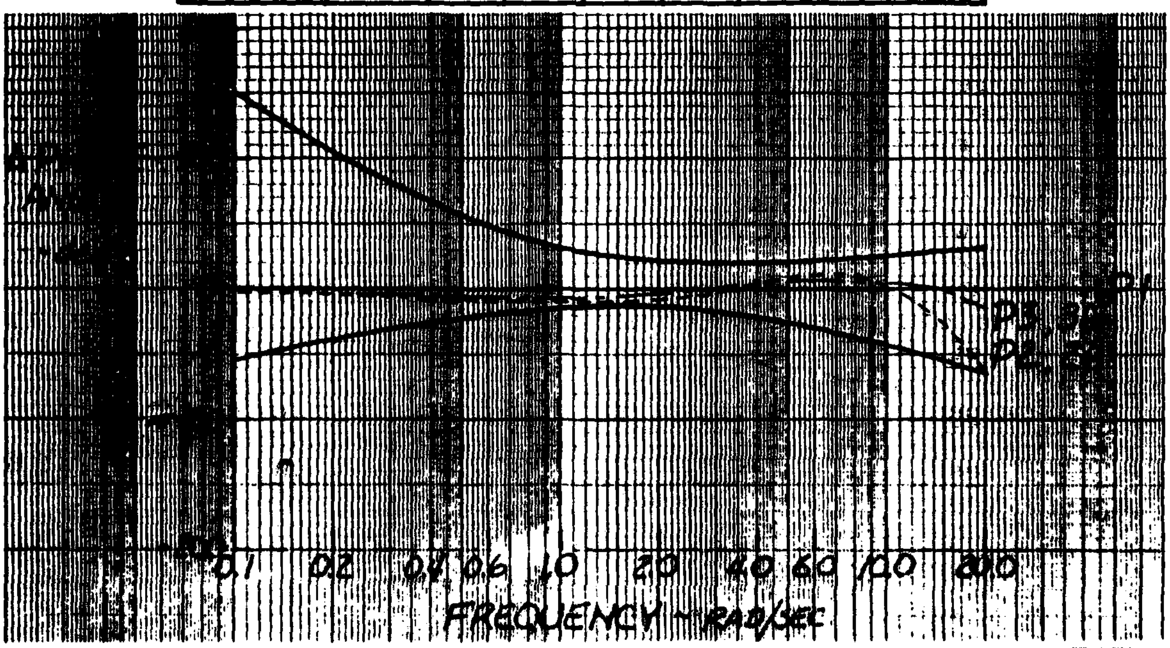
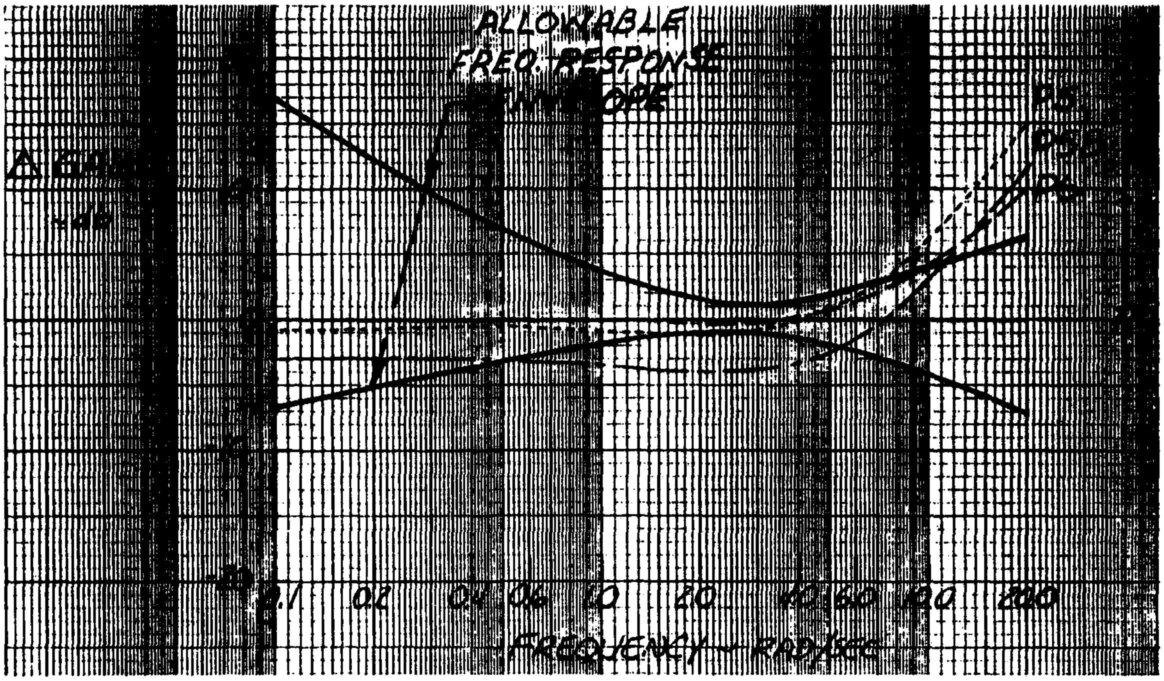


Figure 13a. Equivalent System Mismatches with P1 (HOS) Analytical Response Calculations



Pilot Rating	Configuration	ω	ζ	L_α	τ	Remarks
3	———————— P4	–	–	–	–	HOS-2
6	·············· P5	1.9	1.4	0.55	0.12	ES for P4, L_α Fixed
3	— — — P5B	1.9	1.4	0.55	0.12	P5 with Gain Changed
4	— — — — P6	5.3	0.7	12.5	0.06	ES for P4, L_α Free

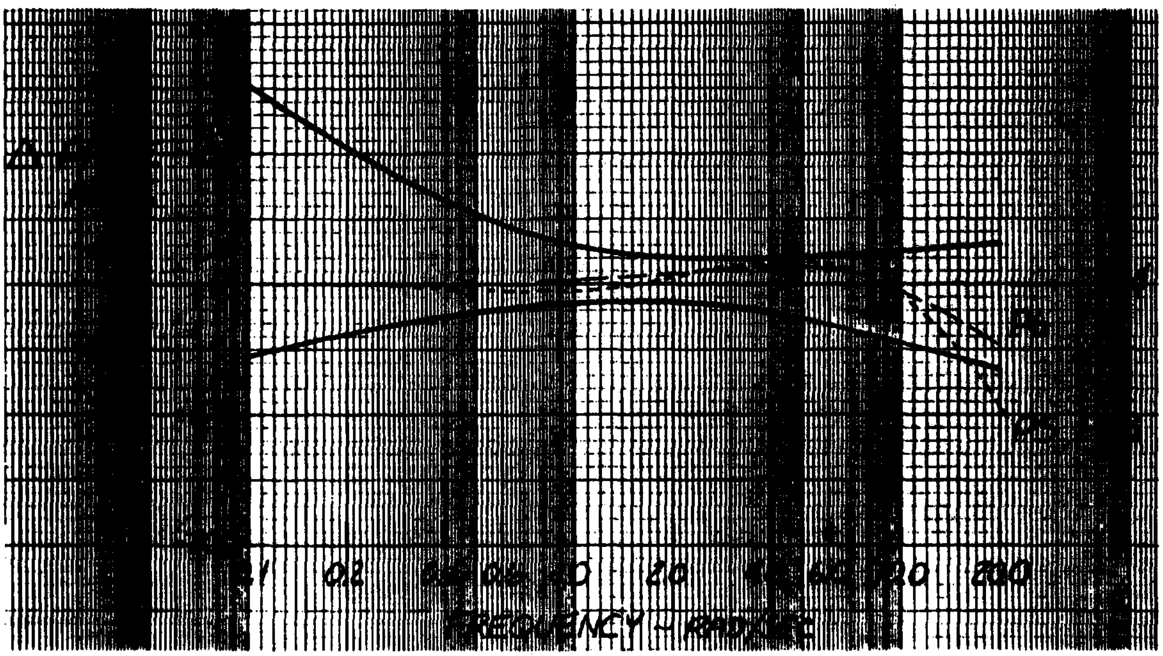


Figure 13b. Equivalent Systems Mismatches with P4 (HOS)
Faired Fourier Transform Data

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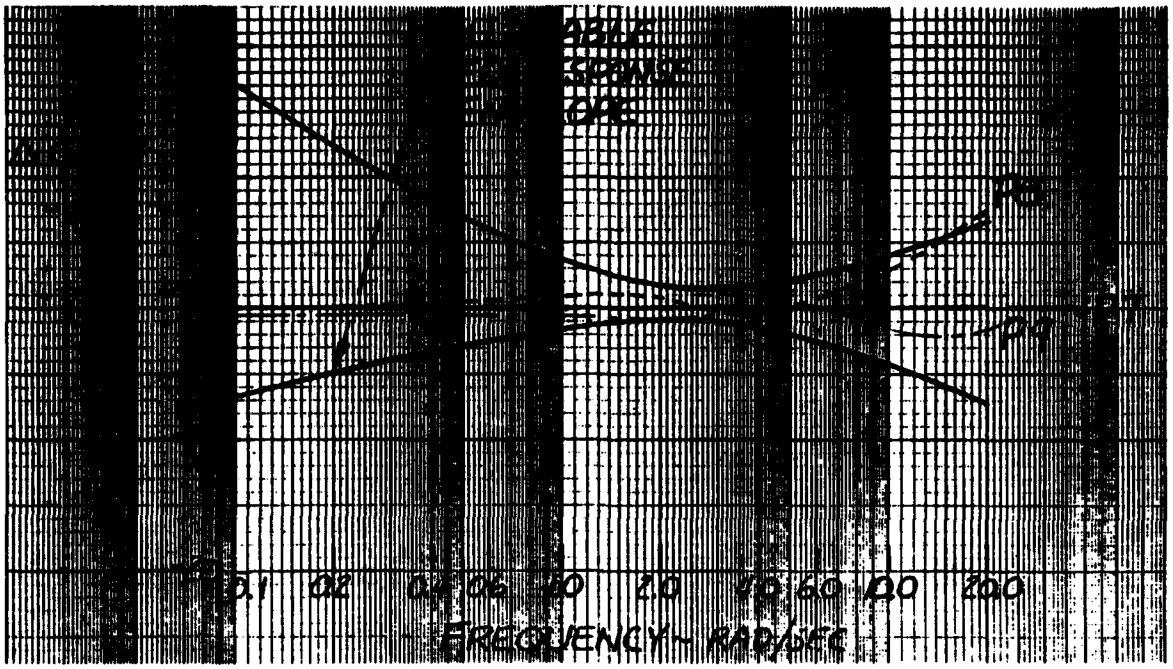

Pilot Rating	Configuration	ω	ζ	L_α	τ	Remarks
4	P7	–	–	–	–	(HOS-LAHOS Config 4-3)
5	— — — — P8	1.6	0.8	0.8	0.10	ES for P7, L_α Fixed
3	——— — — P9	2.6	0.6	∞	–	ES for P7, L_α Free

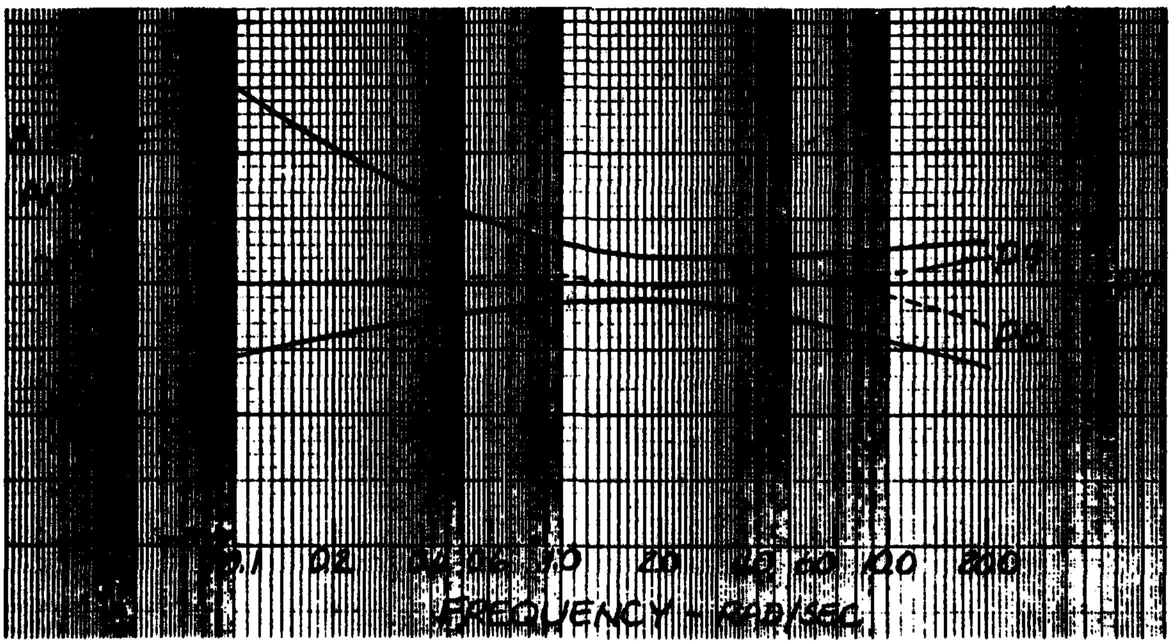

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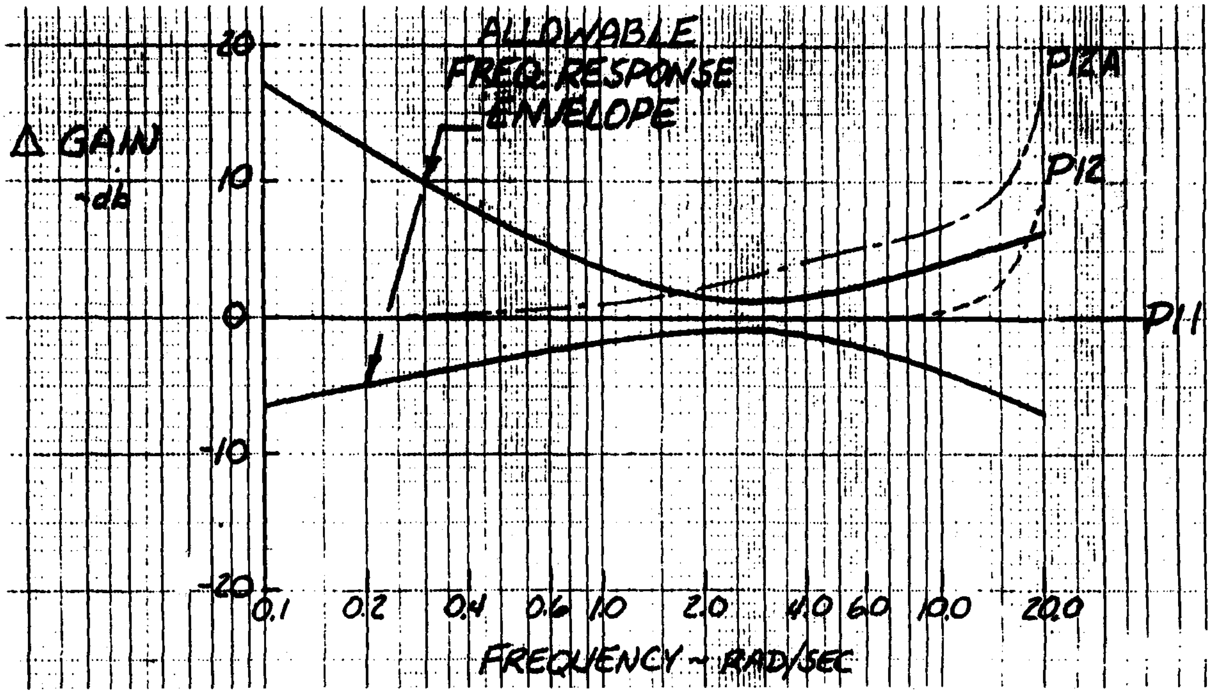
Figure 13c. Equivalent System Mismatches with P7 (HOS) Faired Fourier Transform Data



Pilot Rating	Configuration	ω	ζ	L_α	τ	Remarks
6	P11	–	–	–	–	HOS-LAHOS 2-11
9	— — — — P12	2.6	0.6	0.8	0.17	ES for P11, L_α Fixed
10	— — — P12A	2.6	0.6	0.8	0.17	P12 with S+2/S+6 Filter Added

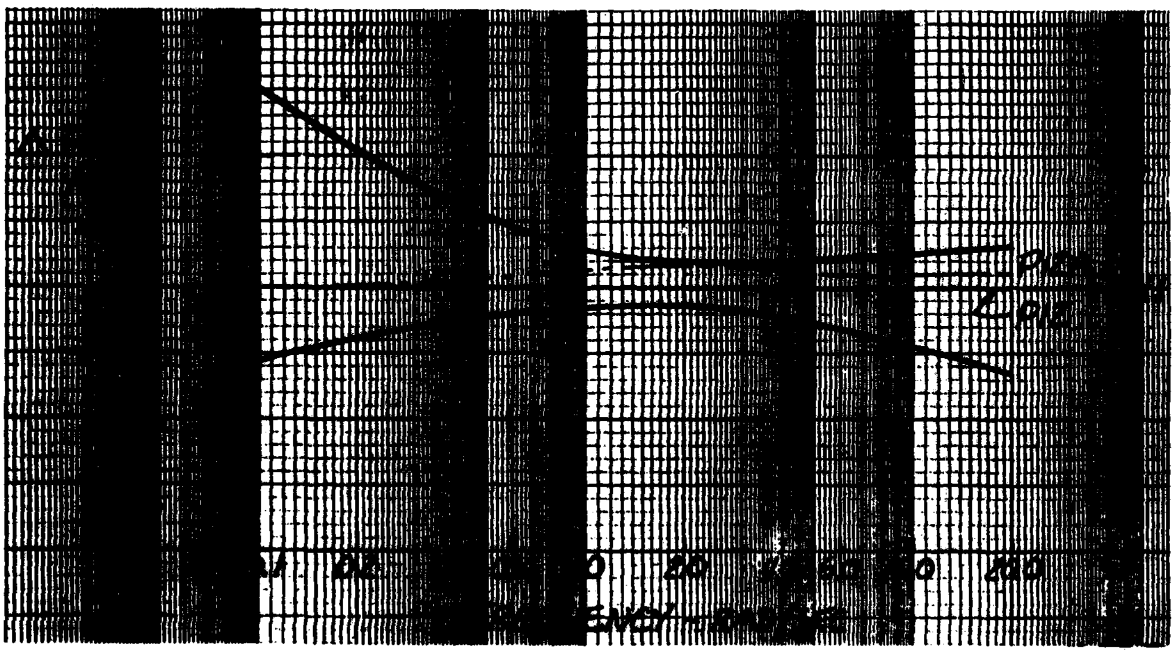
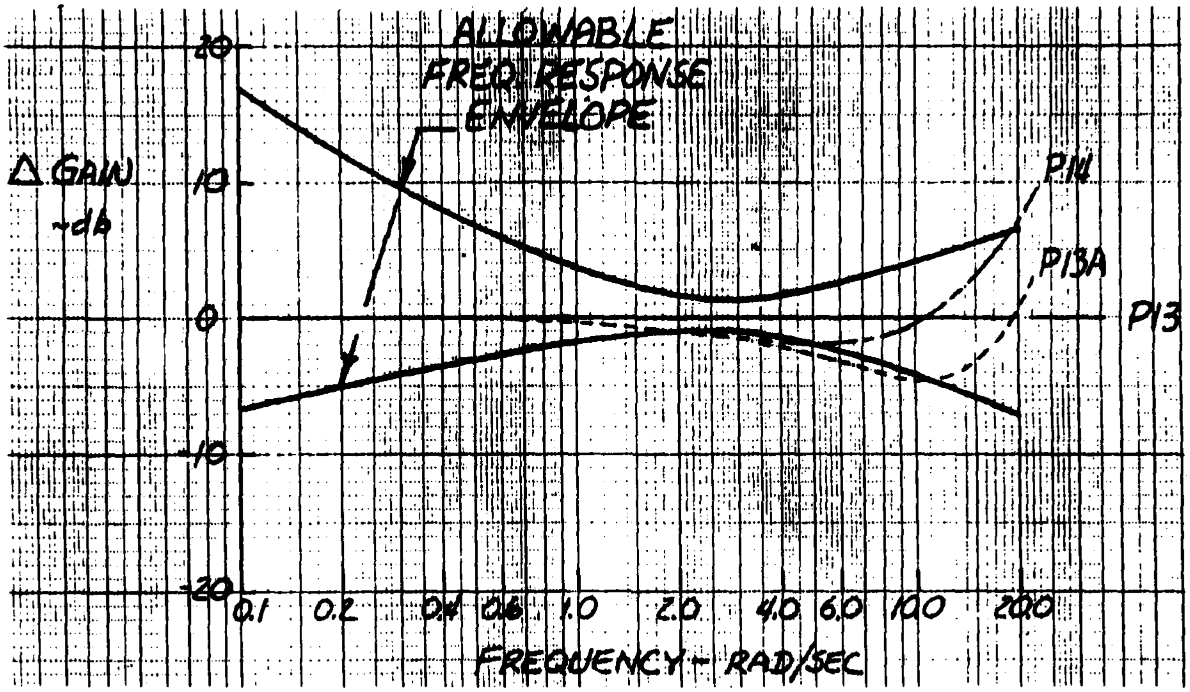


Figure 13d. Equivalent Systems Mismatches with P11 (HOS) Faired Fourier Transform Data



Pilot Rating	Configuration	ω	ζ	L_α	τ	Remarks
3	——————— P13	–	–	–	–	HOS-LAHOS 4-7
6	— — — — — P13A	–	–	–	0.05	P13 Plus Feel System
5	——— — —— P14	2.1	1.0	0.8	0.09	ES for P13, L_α Fixed

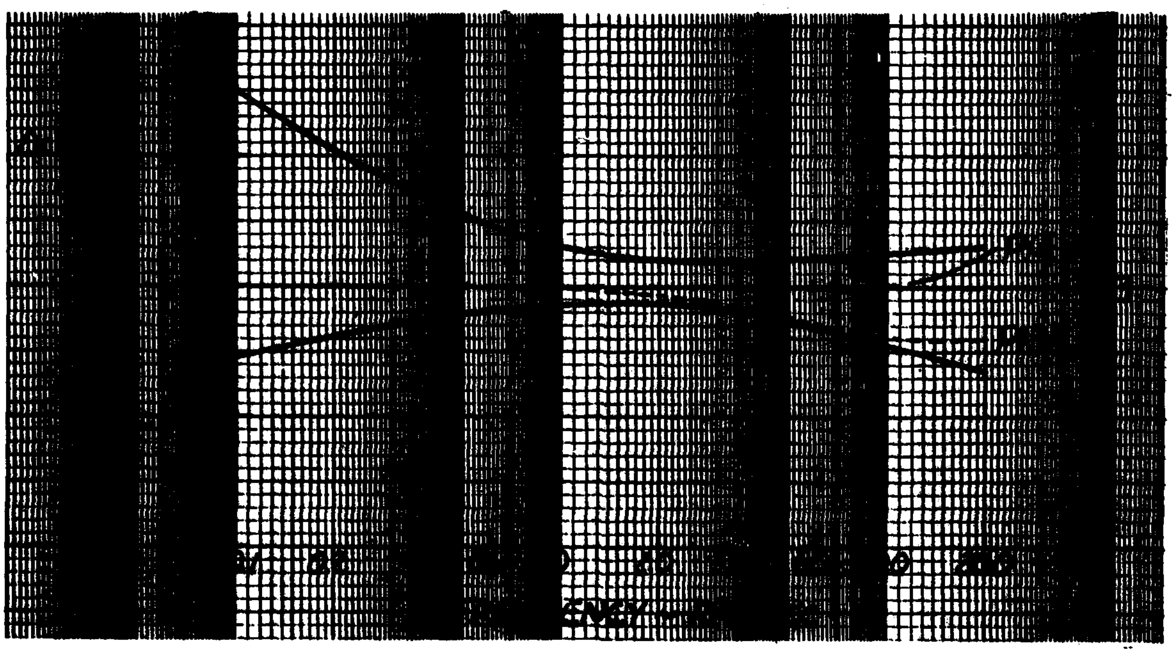


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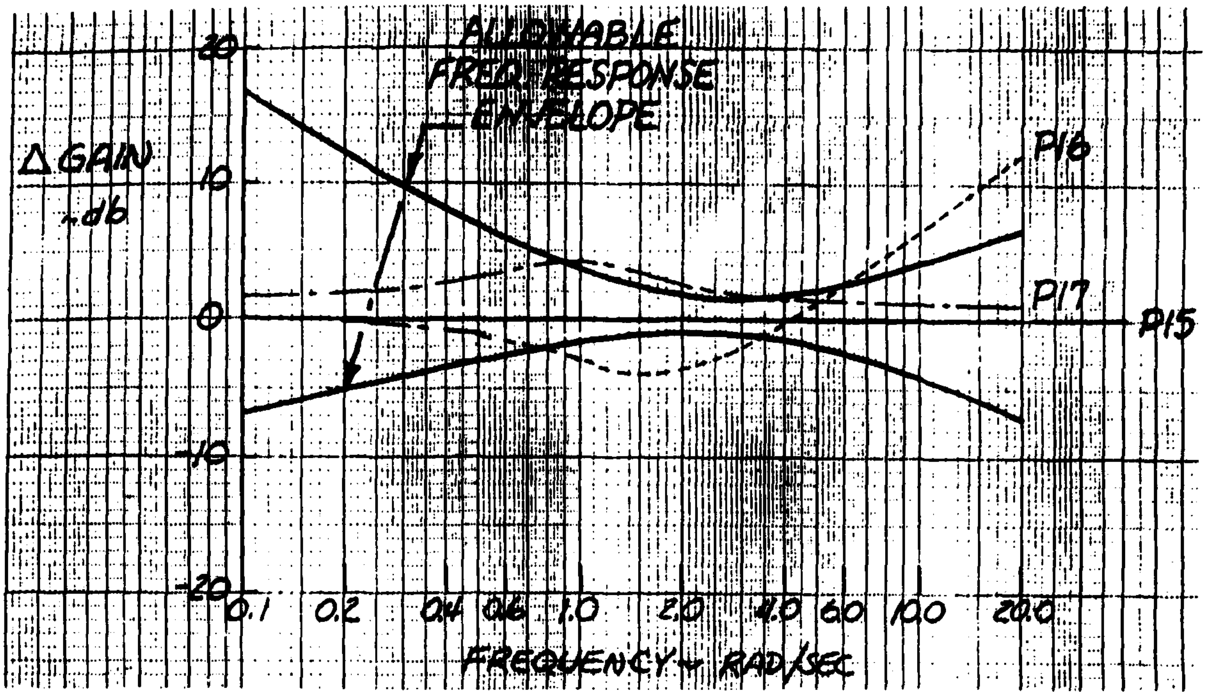
Figure 13e. Equivalent Systems Mismatches with P13 (HOS) Faired Fourier Transform Data



Pilot Rating	Configuration	ω	ζ	L_α	τ	Remarks
8	P15	–	–	–	–	HOS-LAHOS 1-4
8	– – – – – P16	0.8	0.6	0.8	0.16	ES for P15, L_α Fixed
9	—·—·— P17	1.9	0.8	–	–	ES for P15, L_α Free

GP13-0284-16

Figure 131. Equivalent Systems Mismatches with P15 (HOS) Faired Fourier Transform Data

Two types of lead/lag networks were tested. The first, $\frac{(S+2)}{(S+6)}$, was designed to negate all phase lag introduced by the fourth order lag pre-filter at approximately the short period frequency. It can be considered a 'fix' for an aircraft which does not meet the lag requirement of the MIL Spec. The second, $\frac{(S+10)}{(S+20)}$, was designed to introduce lead compensation at higher frequencies. Note that lead/lag compensation can eliminate phase lag due to time delay only in a restricted frequency range. This is because time delay produces phase lag proportional to frequency, and a lead/lag introduces only a local phase shift. For first order compensation, phase shift is theoretically limited to 90° and in a practical implementation is limited to less than 90°.

Figure 14 shows Bode plots of the two lead/lag networks added to configuration P12. Due to the limitations of the simulation equipment, it was not possible to add the lead/lag network directly to the high order baseline system (P11). Because of this, the compensation network was added to the equivalent system (P12) for evaluation of lead/lag effects. The validity of the conclusions should not be affected by the use of this technique, since the equivalent system was flown and directly compared to the high order system. The result of this comparison showed a negligible change in pilot's comments and ratings (see Appendix A).

Figure 15 shows, for clarification, the Bode plots of the incremental response characteristics of the two filter networks. The respective frequency ranges of filter effectivity on responses are apparent, without the baseline system or steady state gain variations superimposed. A summary of the different configurations and Cooper-Harper pilot rating is shown below.

Config	Comments	Lead/Lag Network	Steady State Gain	Cooper-Harper Pilot Rating
P11	Baseline High Order System	None	.4	6
P12A	Equiv. System of Baseline H.O.S.	$\frac{S+2}{S+6}$	.4	10
P12D	Equiv. System of Baseline H.O.S.	$\frac{S+2}{S+6}$	.2	8
P12B	Equiv. System of Baseline H.O.S.	$\frac{S+10}{S+20}$	.9	9
P12C	Equiv. System of Baseline H.O.S.	$\frac{S+10}{S+20}$	.5	5

Steady state gain variation showed the effect of different initial and final response characteristics. Pilot comments indicated that the abruptness of response following the time delay was particularly troublesome with low frequency lead compensation and unchanged steady state gain. Reducing the gain reduced this abruptness but the flying qualities were still not a significant improvement over the uncompensated dynamics.

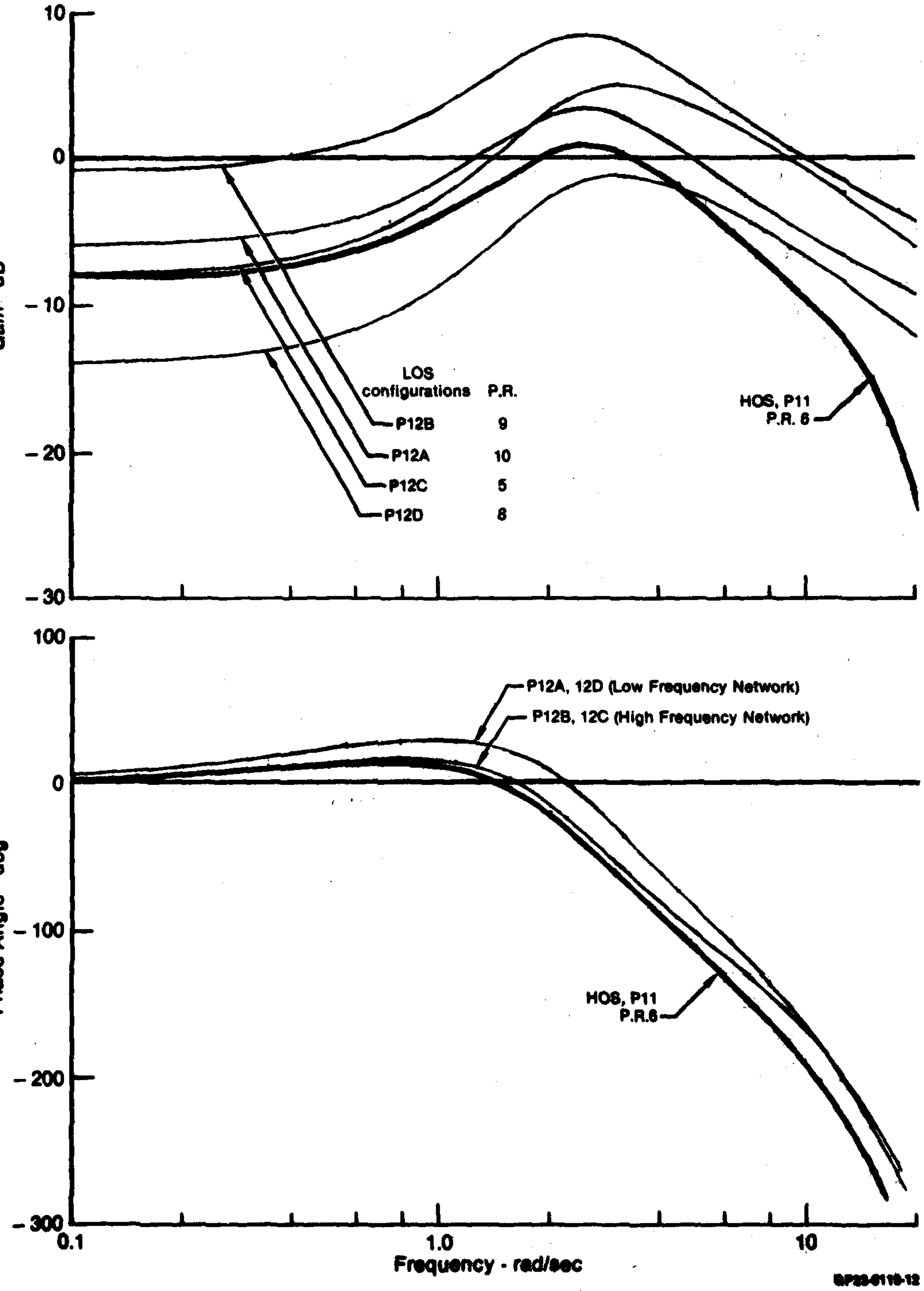


Figure 14. Frequency Responses for Pitch Rate to Stick Force and Pilot Ratings for Configuration with Delay and for Configurations Cancelling Phase Lag at Low and High Frequencies

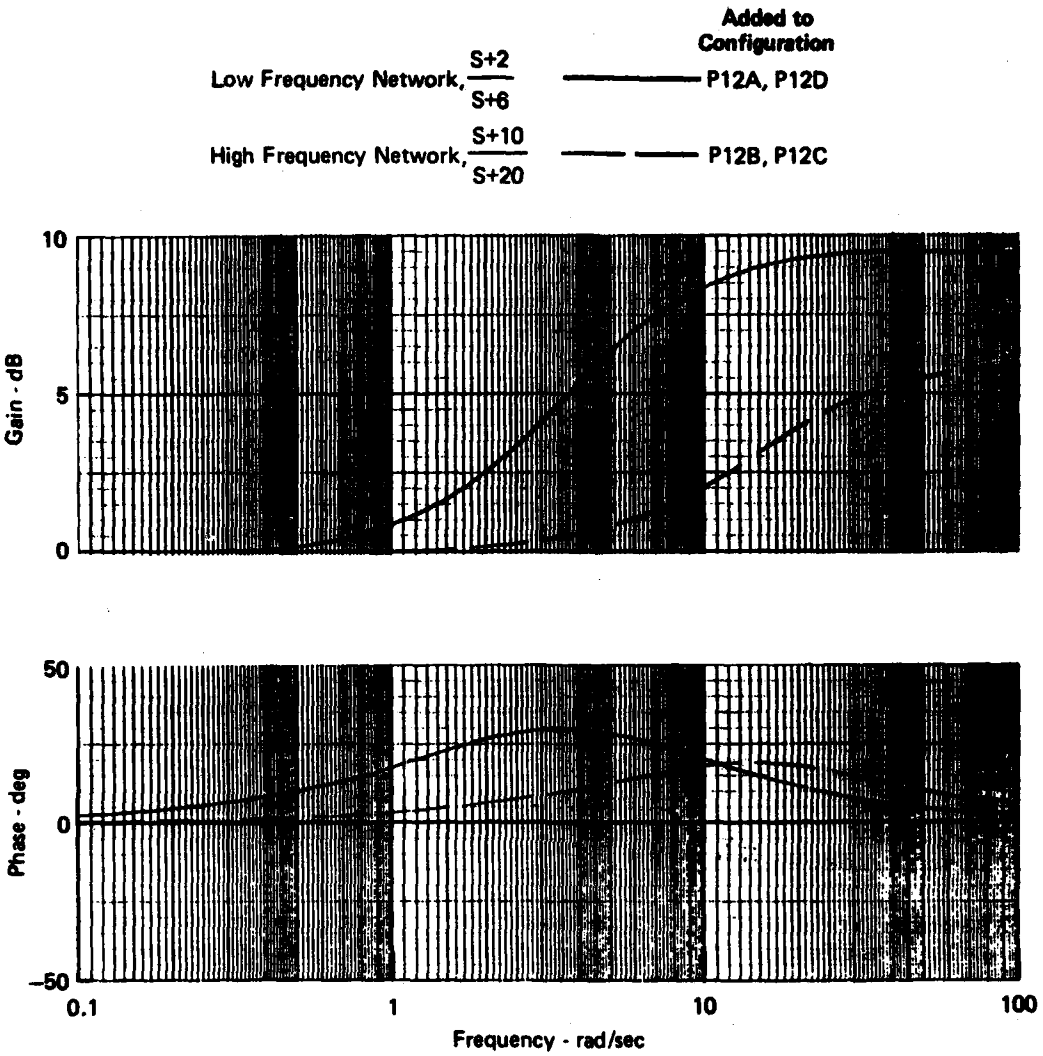


Figure 15. Analytical Frequency Response Increments, Lead/Lag Filter Networks

The data, pilot comments, and ratings show that the lead compensation only affects the response after a finite time, and the initial response remains unchanged. The pilot feels the initial slow response and acts accordingly, then the lead comes into play with an abrupt onset, giving the pilot a totally different set of control dynamics. This is verified by equivalent systems determined for the lead compensated dynamics. The most visible example of this is where the baseline, Configuration P11 (PR = 6), was given low frequency compensation, P12A. The pilot entered a violent PIO in the flare maneuver and the rating was degraded to 10.

While the lead/lag filters can be designed to reduce phase lags at a specific frequency, the wide band (i.e., frequency) effects are detrimental to handling qualities. For these reasons, lead/lag filters are not suitable for piloting tasks requiring accurate flight path and/or attitude control.

The results are inconclusive. It is apparent from the rating summary of Configuration 12 versions that the high frequency gain is important and must be adjusted to compensate for the high frequency amplification effects of the filters. When this adjustment is made - as in Configuration 12C compared with Configuration 12 (Pilot A) - the pilot rating improves although the comments still indicate PIO problems. In contrast, Configuration 12D (Pilot A; Pilot B rating is excluded as discussed in Section VI-1.a) compared with Configuration 12 shows no significant change in rating with the gain adjusted. Clearly, more evaluation data are required before sensible comments on the effects of selective filtering can be made. It is also clear that the full effects of such filters should be evaluated before they are incorporated into a design.

c. <u>Time Delay Effects</u> - The results for Configuration P10A-D, and P12 represent a mini-experiment to investigate the effects of added time delay. Pilot ratings from Pilots A and B are plotted in Figure 16; the time delay is additional transport time delay incorporated into the system and does include sufficient effective time delay for the analog filters inherent in the time delay network circuit and the effective delay from the high frequency elevator actuator (approximately 45 millisec plus 20 millisec, respectively).

Results indicate a threshold of about 145 millisecs before time delay affects the flying qualities of a basic Level 1 aircraft. The Level 1 boundary is approximately 165 ms including all increments of equivalent delay; Level 2 boundary is 215 ms.

Flight data with Pilot A in Configuration P10, 10C and 10D are plotted in frequency response form in Figure 17. The larger phase lags at high frequency, caused by increased time delay, correspond to degradation in pilot rating.

d. <u>Task Observations</u> - The critical part of the evaluation task was the flare and touchdown portion of the task - the last 50 ft before touchdown - as previously observed in Reference 4. It is therefore imperative that actual touchdowns be included in evaluation tasks designed to expose potential longitudinal approach and landing flying qualities problems. Therefore, the evaluation pilots should be reminded of the importance to adhere to the ground rules for the investigation as defined in Section V. Further, the pilot must be instructed to make precise positive landings, not just allow the aircraft to settle. If necessary, the task may be tightened artificially (such as by glideslope and localizer offsets) in order to force high-bandwidth control inputs.

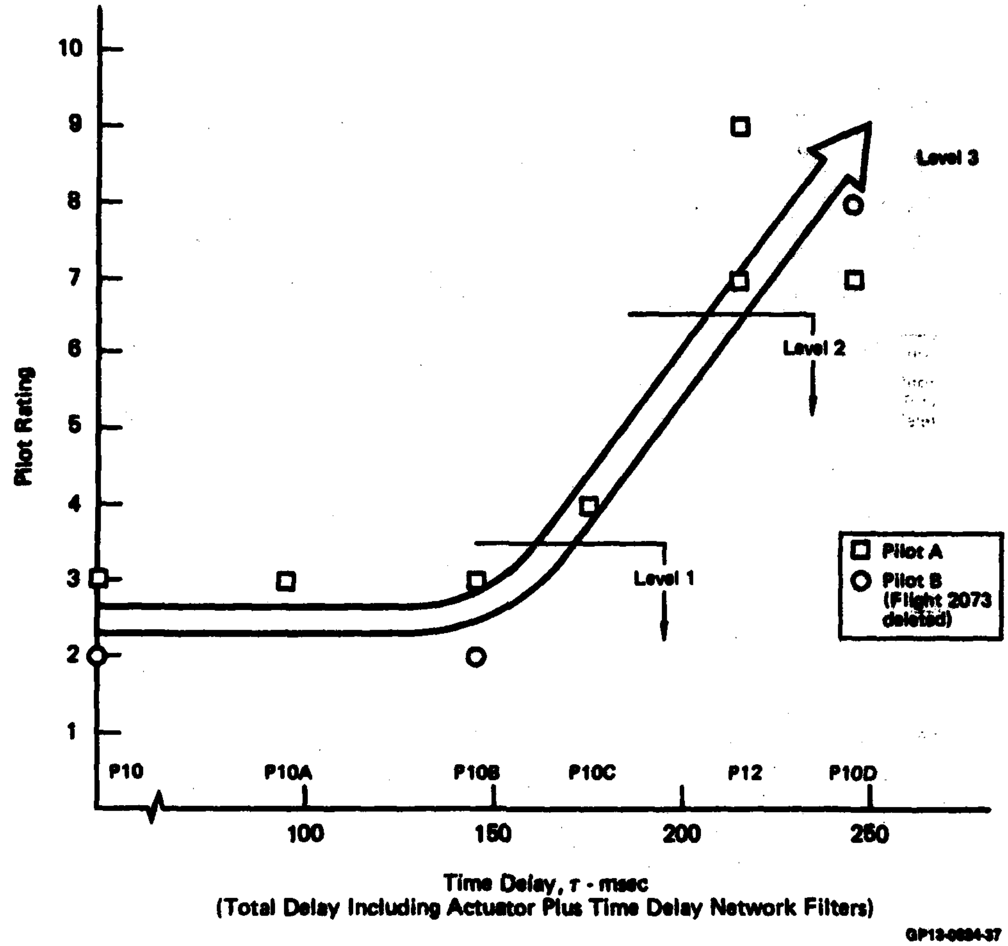


Figure 16. Effect of Time Delay (Pitch)

3. COMPARISON OF LONGITUDINAL DATA WITH MIL-F-8785C - The low order equivalent system parameters are used in evaluating the longitudinal maneuvering and dynamic characteristics as specified in MIL-F-8785C. In Table 7, the Level for each of the configurations and short-period requirements is compared with the Level based on the Cooper-Harper operational ratings reported by the pilots. The basic configuration for this experiment is a Level 1 aircraft based on MIL-F-8735C boundaries (see Figures 18 and 19) and is essentially configuration 2-1 from Reference 4.

Correlation between the specification items and the pilot evaluation of handling qualities is good in Table 7. The few instances of discrepancy were the lags, and sometimes also the damping ratio; the specification generally assigned the configuration an equal or worse Level than the pilots' rating. When the pilot rating resulted in a better Level, the phase lag or time lag differences were borderline cases between Levels for the specification definition.

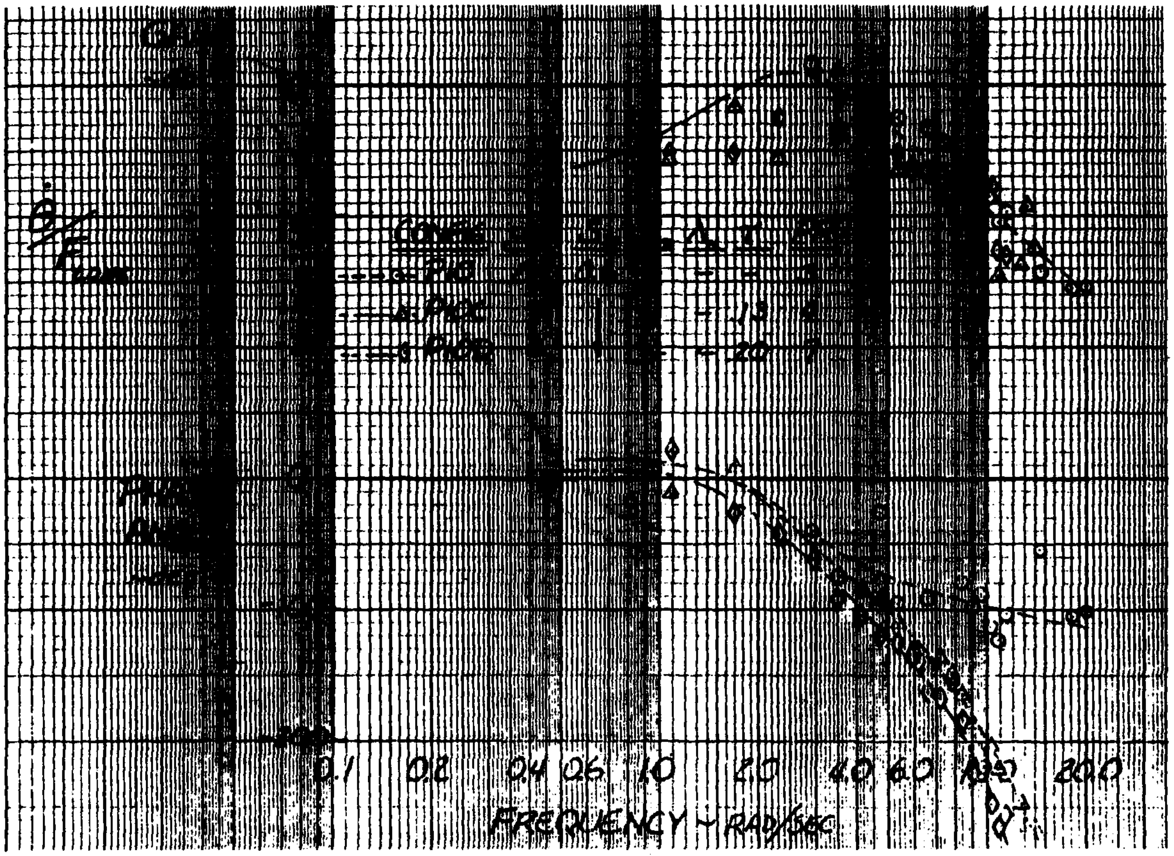


Figure 17. Effect of Time Delay

4. <u>LATERAL EXPERIMENT DATA</u> - The lateral pilot rating data are presented in Table 8; pilot comments are summarized in Appendix B. Included in the table are the necessary configuration characteristics to allow, in conjunction with the data from Section III, construction of the complete configuration roll rate transfer function.

In effect, the data are divided into three subexperiments:

- Equivalent system verification (L1 through L4)
- Effect of control system lag and time delay with "short" τ_R, high roll damping (L5 through L11)
- Effect of control system lag and time delay with "long" τ_R, medium roll damping (L12 through L16)

TABLE 7

LONGITUDINAL FLYING QUALITIES
CORRELATION WITH MIL-F-8785C

CONFIG	LEVELS OF FLYING QUALITIES PER MIL-F-8785C: MANEUVERING CHARACTERISTICS ωn_{SP} & n_z/α	ζ_{SP}	F_S/n	DYNAMIC CHARACTERISTICS: ALLOWABLE PHASE LAG	ALLOWABLE TIME DELAY	LEVELS BASED ON PILOT RATINGS FROM ESP DATA
PARA.	3.2.2.1.1	3.2.2.1.2	3.2.2.3.1	3.5.3 (TABLE XVIII)	3.5.3 (TABLE XIV)	
P2	1	1	1	2	2	1
P2A	1	1	1	2	2	2
P3	1	1	1	1	1	1
P3A	1	1	1	1	1	1
P5-1	1	2	1	2	2	2
P5-2	1	2	1	2	2	2
P5A	2&3	2	1	1	2	3
P5B	1	2	1	2	2	1
P5C	1	2	1	2	2	1
P6	1	1	1	2	1	2
P7	1	1	1	1	1	1
P8	1	1	1	1	2	2
P9	-	1	1	1	1	1
P10	1	1	1	1	1	1
P10A	1	1	1	1	1	1

TABLE 7 (Concluded)

LONGITUDINAL FLYING QUALITIES
CORRELATION WITH MIL-F-8785C

CONFIG	LEVELS OF FLYING QUALITIES PER MIL-F-8785C: MANEUVERING CHARACTERISTICS $\omega_{n_{SP}}$ & n_z/α	ζ_{SP}	F_S/n	DYNAMIC CHARACTERISTICS: ALLOWABLE PHASE LAG	ALLOWABLE TIME DELAY	LEVELS BASED ON PILOT RATINGS FROM ESP DATA
PARA.	3.2.2.1.1	3.2.2.1.2	3.2.2.3.1	3.5.3 (TABLE XVIII)	3.5.3 (TABLE XIV)	
P10B	1	1	1	1	2	1
P10C	1	1	1	2	2	2
P10D	1	1	1	2	3	3
P11	1	1	1	2	2	2
P12	1	1	1	2	3	3
P12A	1	1	1	2	3	3
P12B	1	1	1	2	3	3
P12C	1	1	1	2	3	2
P12D	1	1	3	2	3	3
P13	1	1	1	2	2	1
P14	1	1	1	1	2	2
P15	2&3	1	1	2	2	3
P16	2&3	1	1	2	3	3
P16A	2&3	1	1	2	2	3
P17	2&3	1	1	1	1	3

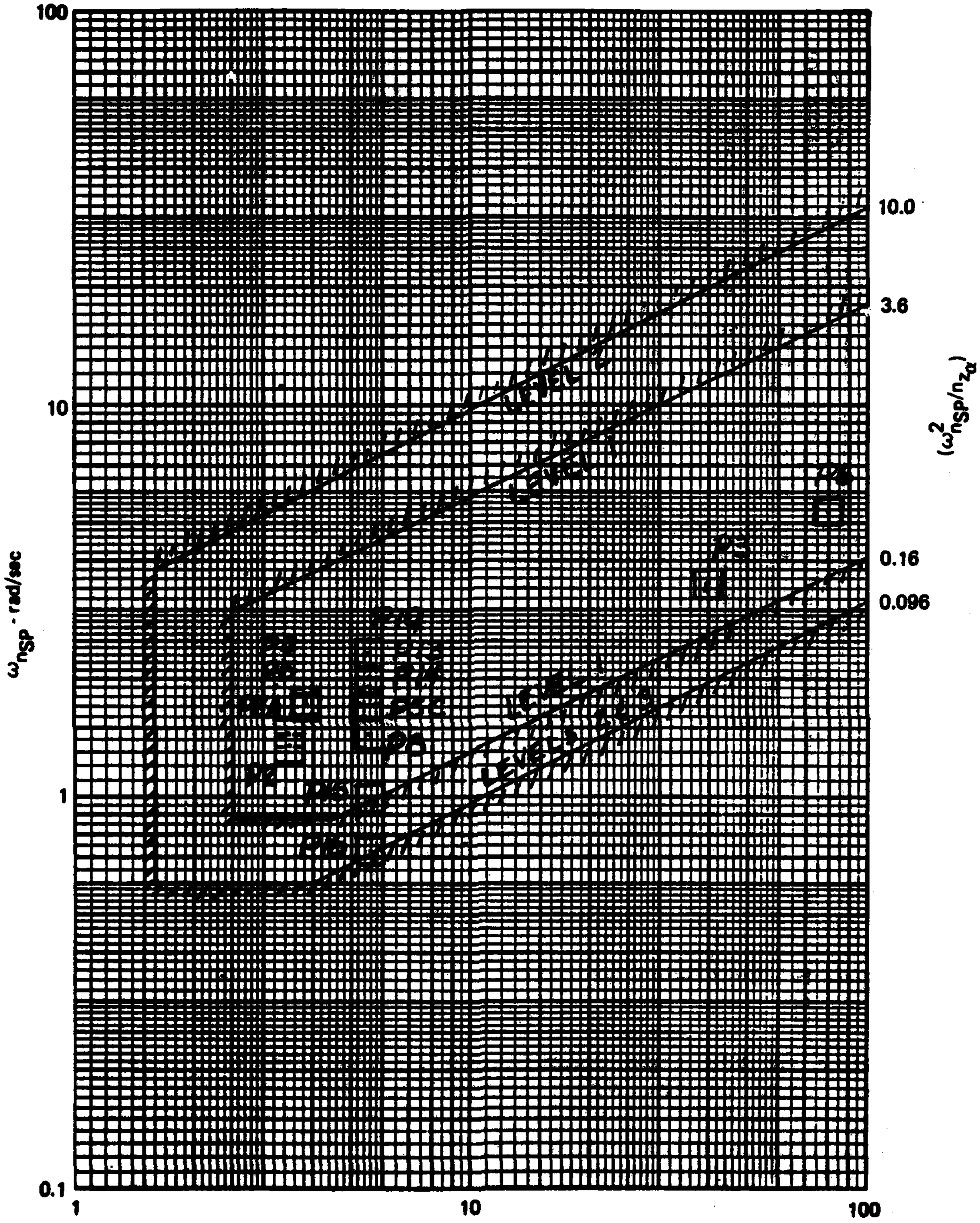


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Figure 18. Short-Period Frequency and Acceleration Sensitivity Limits, MIL-F-8785C, Para. 3.2.2.1.1

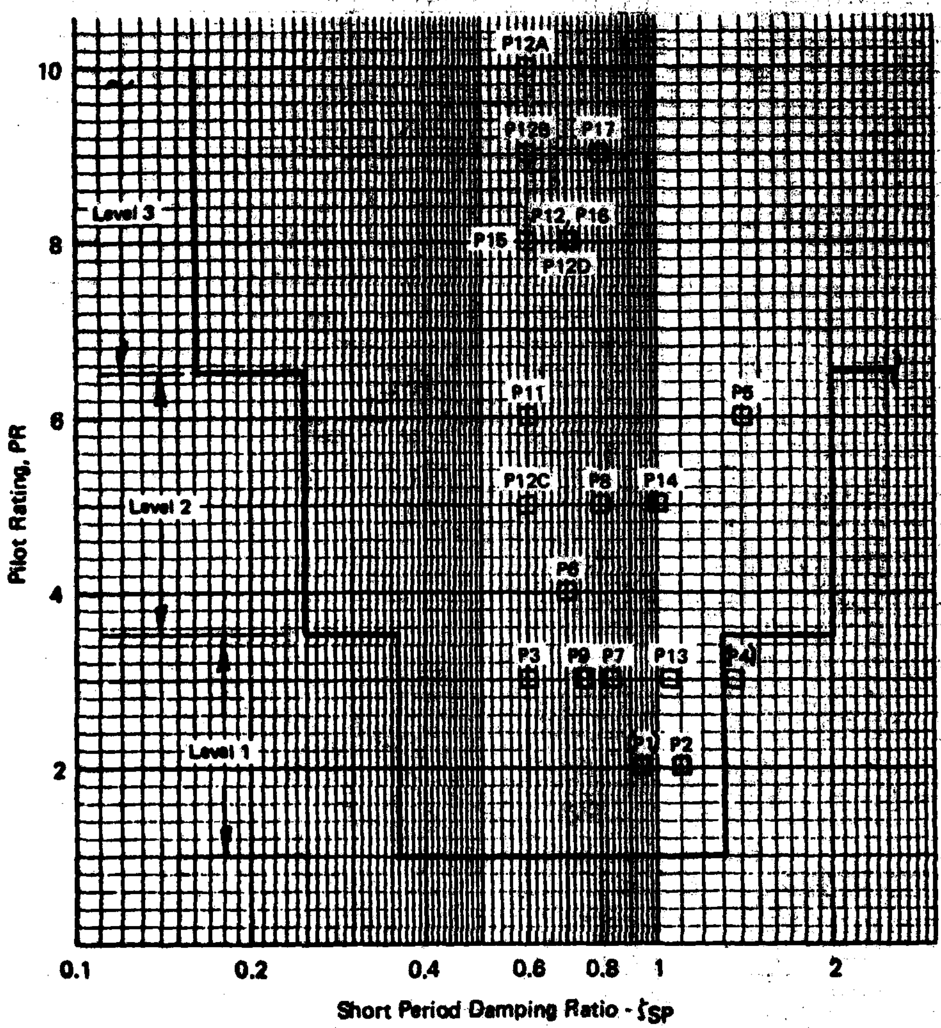


Figure 18. Short-Period Damping Ratio Limits, MIL-F-8785C Para 3.2.2.1.2

Because of the time constraints in the program, fixed lateral gains were used in the NT-33 which resulted in variations in τ_R and $L'_{F_{AS}}$ as lateral inertia changed with fuel changes. This effect was only significant above 360 gals fuel remaining (fuel in the tip tanks). The values of corrected τ_R, and $L'_{F_{AS}}$ reflect these inertia effects and the effects of flying the approaches at essentially constant angle of attack.

For the variations in τ_R from the nominal values of 0.4 and 0.9 secs which resulted from using constant NT-33 gains, no significant trend of pilot rating can be found. For our purposes, therefore, the two values of τ_R simulated were: 0.4 sec and 0.9 sec.

TABLE 8

LATERAL ESP DATA SUMMARY

CONF.	PILOT	FLT.	τ_R (nominal) (sec)	(2) $\tau_{R_{CORRECT}}$ (sec)	FILTER λ_D	FILTER λ_N	FILTER CARD	(1) TIME DELAY (sec)	$L'_{F_{AS}}$ (2) $(\frac{r/s^2}{lb})$	p_{ss}/lb $(\frac{°/sec}{lb})$	FUEL (gals)	PR	SPR
L1	A	2083	(HOS-3)	-	-	-	-	-	.65	5	300	4	4
L2	A	2083	.45	.5	20	-	-	.07	.25	6	250	3	4
L3	A	2080	(HOS-4)	-	-	-	-	-	.46	5	450	4	5
L4	A	2080	.45	.5	20	-	-	.05	.38	10	200	4	4
L4A	A	2080	.45	.5	20	-	-	.05	.28	7	300	3	3
L5	A	2077	.40	.6	20	-	-	-	.14	4	450	2	2
	C	2084	.40	.6	20	-	-	-	.16	5	450	2	2
	D	2081	.40	.5	20	-	-	-	.19	4	400	2	1
L5A	D	2076	.40	.6	-	-	-	-	.11	3	450	3	3
L6	A	2078	.40	.4	10	-	-	-	.23	5	250	2	2

TABLE 8 (Continued)

LATERAL ESP DATA SUMMARY

CONF.	PILOT	FLT.	τ_R (nominal) (sec)	$\tau_{R_{CORRECT}}$ (sec) (2)	FILTER λ_D	FILTER λ_N	FILTER CARD	TIME DELAY (sec) (1)	$L'_{F_{AS}}$ (2) $(\frac{r/s^2}{lb})$	p_{ss}/lb $(\frac{°/sec}{lb})$	FUEL (gals)	PR	SPR
L7	A	2079	.40	.4	5	–	–	–	.23	5	150	3	2
L7A	A	2083	.40	.4	5	–	–	.09	.23	5	100	4	3
L8	A	2078	.40	.6	2	–	–	–	.16	5	450	5	5
L8A	A	2079	.40	.4	1	–	–	–	.30	7	200	6	5
L8B	A	2086	.40	.4	.7	–	–	–	.23	5	150	9	8
	D	2081	.40	.4	.7	–	–	–	.23	5	100	5	6
L9	A	2079	.40	.4	20	–	–	.09	.23	5	300	2	2
L10	A	2077	.40	.4	20	–	–	.14	.23	5	200	5	4
L10A	D	2076	.40	.4	–	–	–	.14	.15	3	300	3.5	4
L11	A	2078	.40	.4	20	–	–	.20	.19	4	100	3	4
	C	2084	.40	.4	20	–	–	.20	.19	4	250	5	5

TABLE 8 (Continued)

LATERAL ESP DATA SUMMARY

CONF.	PILOT	FLT.	τ_R (nominal) (sec)	(2) $\tau_{R_{CORRECT}}$ (sec)	FILTER λ_D	FILTER λ_N	FILTER CARD	(1) TIME DELAY (sec)	$L_{F_{AS}}$ (2) $(\frac{r/s^2}{lb})$	p_{ss}/lb $(\frac{°/sec}{lb})$	FUEL (gals)	PR	SPR
L11A	C	2084	.40	.4	20	–	–	.20	.23	5	250	6	5
L11B	C	2084	.40	.4	20	–	–	.20	.15	3	250	4	5
L11C	A	2083	.40	.4	20	–	–	.30	.27	6	150	9	9
	D	2081	.40	.4	20	–	–	.30	.23	5	100	6	8
L11D	A	2078	.40	.5	2	–	–	.15	.19	5	400	10	10
L12	A	2083	0.9	1.2	20	–	–	–	.09	6	450	5	4
	A	2077	0.9	1.0	20	–	–	–	.10	6	400	4	4
L12A	D	2076	0.9	.9	–	–	–	–	.10	5	350	3.5	3
L13	A	2079	0.9	1.2	10	–	–	–	.09	6	450	4	4
L14	A	2080	0.9	1.2	5	–	–	–	.09	6	450	5	5
	A	2077	0.9	.9	5	–	–	–	.12	6	300	7	6
	D	2076	0.9	.9	5	–	–	–	.11	5	200	3	3

TABLE 8 (Concluded)

LATERAL ESP DATA SUMMARY

CONF.	PILOT	FLT.	τ_R (nominal) (sec)	$\tau_{R_{CORRECT}}$ (2) (sec)	FILTER λ_D	FILTER λ_N	FILTER CARD	TIME DELAY (1) (sec)	$L_{F_{AS}}$ (2) $(\frac{r/s^2}{lb})$	p_{ss}/lb $(\frac{°/sec}{lb})$	FUEL (gals)	PR	SPR
L14A	A	2077	0.9	.9	2	-	-	-	.14	7	100	8	8
	D	2081	0.9	.9	2	-	-	-	.12	6	300	3	4
	D	2076	0.9	.9	2	-	-	-	.11	5	150	4	5
L14B	A	2083	0.9	1.2	1	-	-	-	.09	6	450	10	10
	C	2084	0.9	1.0	1	-	-	-	.10	6	400	8	9
L15	A	2083	0.9	.9	20	-	-	.09	.18	9	200	4	3
	A	2078	0.9	.9	20	-	-	.09	.12	6	350	5	5
L16	A	2079	0.9	1.0	20	-	-	.14	.10	6	400	3	5
	A	2078	0.9	.9	20	-	-	.14	.12	6	200	4	4
L16A	A	2080	0.9	.9	20	-	-	.20	.12	6	200	8	8
	D	2081	0.9	1.2	20	-	-	.20	.09	6	450	3	4

NOTES: (1) Time delay is the transport identifier time delay increment added to the NT-33 simulation.

(2) τ_R and $L_{F_{AS}}$ values are corrected for inertia effects for fuel remaining values greater than 350 gals.

In several instances, configurations with special combinations of lag and time delay mistakenly evolved. These configurations are also included in the data summary.

a. Effects on Pilot Rating Data of Pilot Technique - The only comment in this area for the lateral data is to suggest that the data for Pilot D be excluded from any data analysis. Reasons for this comment are given in Subsection VI-1.a.

b. Lateral Equivalence - The NT-33 has a response-feedback variable stability system as opposed to a model-following system. The feedback gains necessary to simulate desired dynamics therefore must be established using prior knowledge of the basic NT-33 calculation of appropriate feedback values, and a series of calibration runs to allow interpolation of gain values. It was decided not to expend a significant part of the limited available time on this activity because of the following factors:

- A generic study of lateral-directional dynamics had not been conducted on the NT-33 for some years, and therefore the lateral directional dynamics of the aircraft with its current equipment had not been verified recently.
- Significant changes in roll inertia occur during a flight as fuel is burned from the tip tanks (as mentioned in VI-3 above).
- The lack of data on lateral augmented dynamics strongly suggested that as large a data base as possible be established as well as addressing the particular question of equivalence.

For these reasons, the exact values of roll mode time constant required for true equivalence were not obtained. The result was relatively high cost functions for the equivalent systems: for L2, $\simeq$ 110; for L4, $\simeq$ 190. Despite these mismatches the pilots ratings were equivalent in the comparison of high order configurations L1 and L3 with L2 and L4 respectively. Since these four configurations are the extent of equivalent system verification cases, additional analysis of low order systems for equivalency is dependent on comparison of lateral equivalent pairs. The mismatch values for these pairs are included in Appendix D with the analytical comparisons of the systems.

Appendix C contains detailed comparisons of the pilot ratings and comments for the lateral equivalent pairs.

5. DISCUSSION OF LATERAL RESULTS

a. Gain Effects - As for the longitudinal data, the gain strategy was to achieve approximately the same values of steady-state roll rate per lb as achieved in the advanced fighter high order systems (HOS-3,4). Selection of the equivalent system gain is clearly an important factor in exploring equivalency; witness

Configuration L4 and L4A. Even when the L4 lateral gain was reduced in Configuration L4A, to agree more closely with HOS-4, the comments still did not indicate equivalency. More data are required before this issue can be properly understood.

For the configurations evaluated with various levels of time delay, it appears that the high frequency gain, $L'_{F_{AS}}$ is an important factor. Configurations L10 and L11C, for example, are downrated by the pilot for abruptness - delayed, then too sensitive - even though the command gain, and therefore $L'_{F_{AS}}$, is similar to that of Configuration L9 which was satisfactory in all respects. Since gain was not varied in an orderly fashion for these configurations, the effects cannot be properly evaluated. It would appear that aircraft with large time delays require lower gains to avoid problems with abruptness. Whether the overall flying qualities can be improved by correct gain selection is a question which is not answered by this exploratory experiment but which needs answering.

b. Lag Effects - The pilot ratings for Pilots A and C are plotted against the time constant ($1/\lambda_D$) of the first-order control system lag in Figure 20. The trends are supported by the frequency response characteristics for two roll mode time constants in Figures 21 and 22.

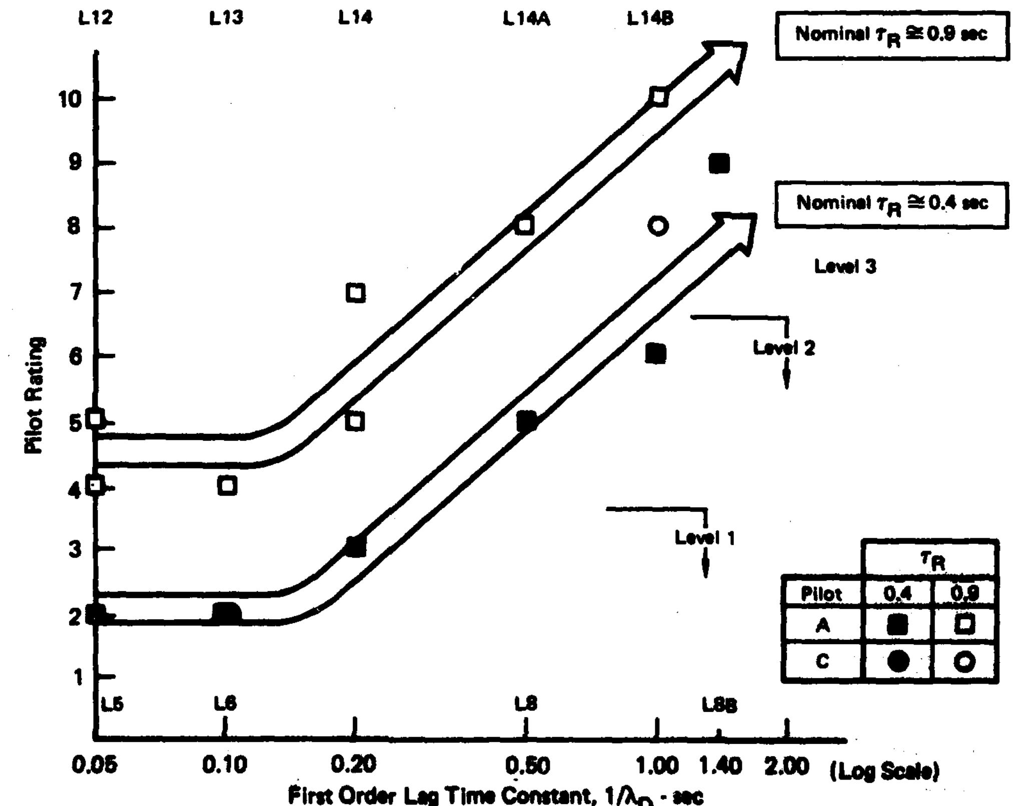


Figure 20. Effect of Lag (Roll)

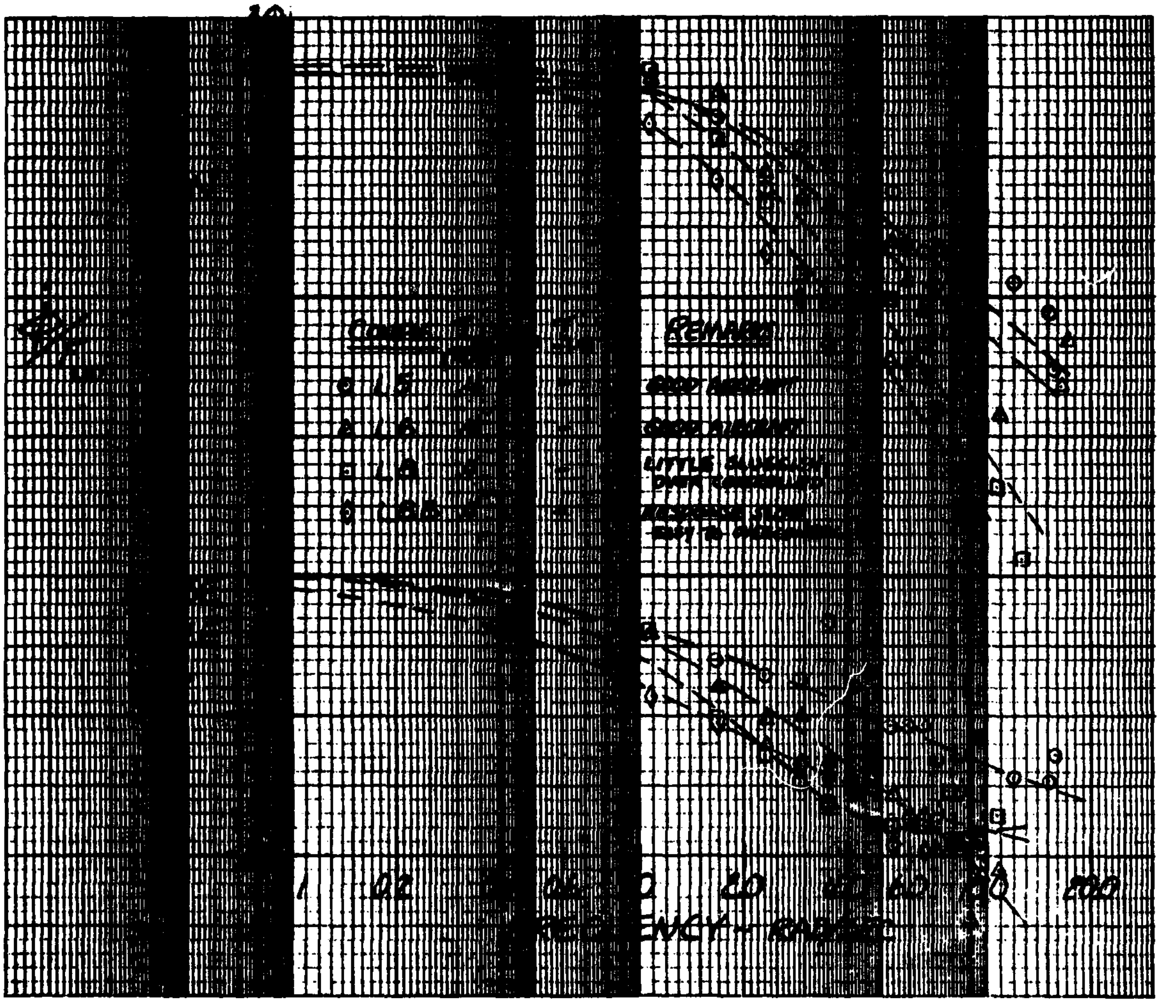


Figure 21. Effect of Lag Time Constant, $1/\lambda_D$, with "Short" τ_R

Both the Level 1 (L5) and the Level 2 (L12) baseline configurations (τ_R of 0.4 and 0.9 secs respectively) are unaffected by control system lag until the time constant reaches about .15 secs. The degradation rate with further increases in time constant is similar for both values of τ_R. Also, for an otherwise satisfactory aircraft the control system lag time constant should be less than .25 secs for Level 1 lateral flying qualities.

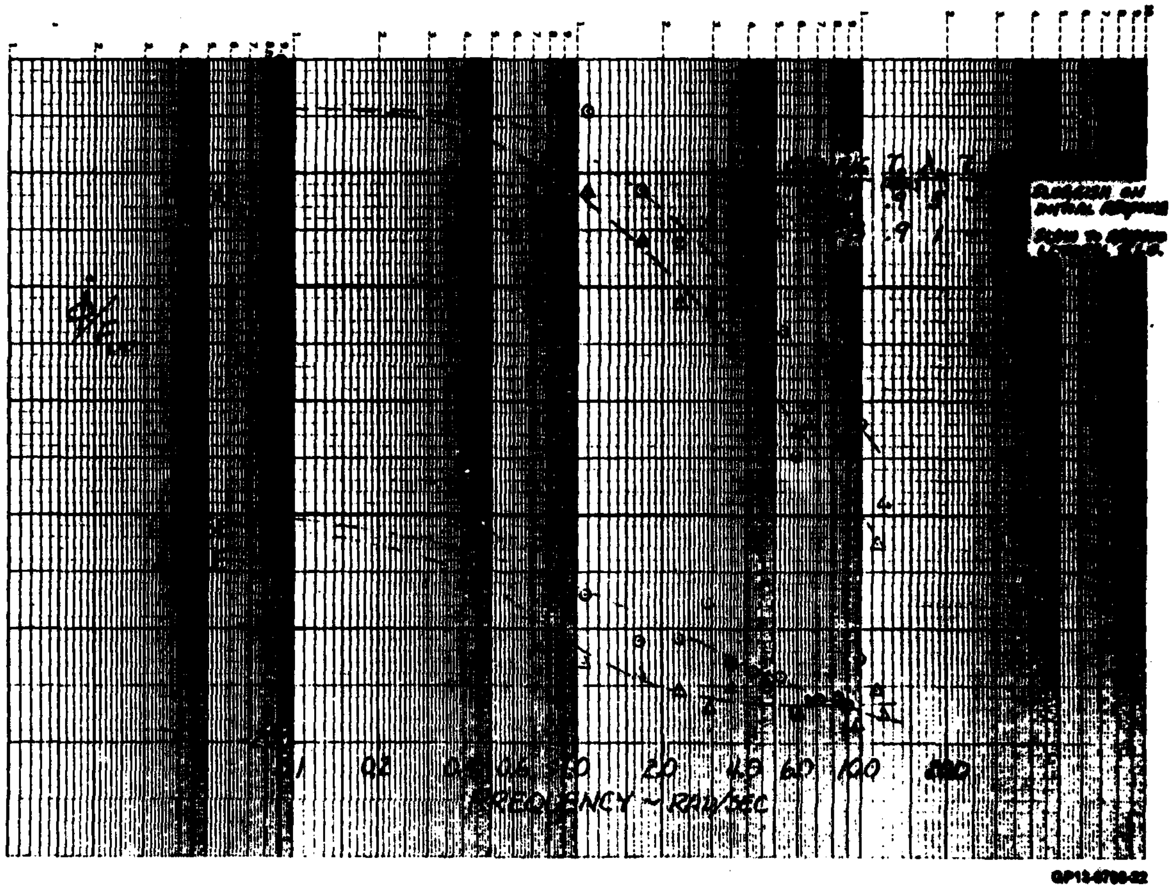


Figure 22. Effect of Lag Time Constant, $1/\lambda_D$, with "Long" τ_R

c. Time Delay Effects - The pilot ratings of Pilots A and C are plotted against the additional time delay in Figure 23. These results are hardly definitive considering the small data set and the scatter in the ratings; however, the following observations can be presented. Note that because of mechanization difficulties, for these configurations with time delays added, a first-order 20 rad/sec filter was also included. The effect of this lag on the flying qualities of the baseline configurati[illegible]s, L5 and L12, is not significant. If it is assumed that Configu[illegible]a-tions L4 and L10 were rated poor because of high command gains, then the trend arrows can be drawn as shown. The trends indicate that both the Level 1 (L5) and Level 2 (L12) baseline configurations are not affected by transport time delays until the delay reaches about 175 millisec. Degradation with further time delay is shown for both base configurations. For an otherwise satisfactory aircraft, the control system time delay should be less than approximately 230 millisec total for Level 1 lateral flying qualities and less than 300 ms for Level 2. Also, Figure 24 illustrates the effects of additional time delay on the frequency response characteristics of Configuration L11C, compared to baseline Configuration L5.

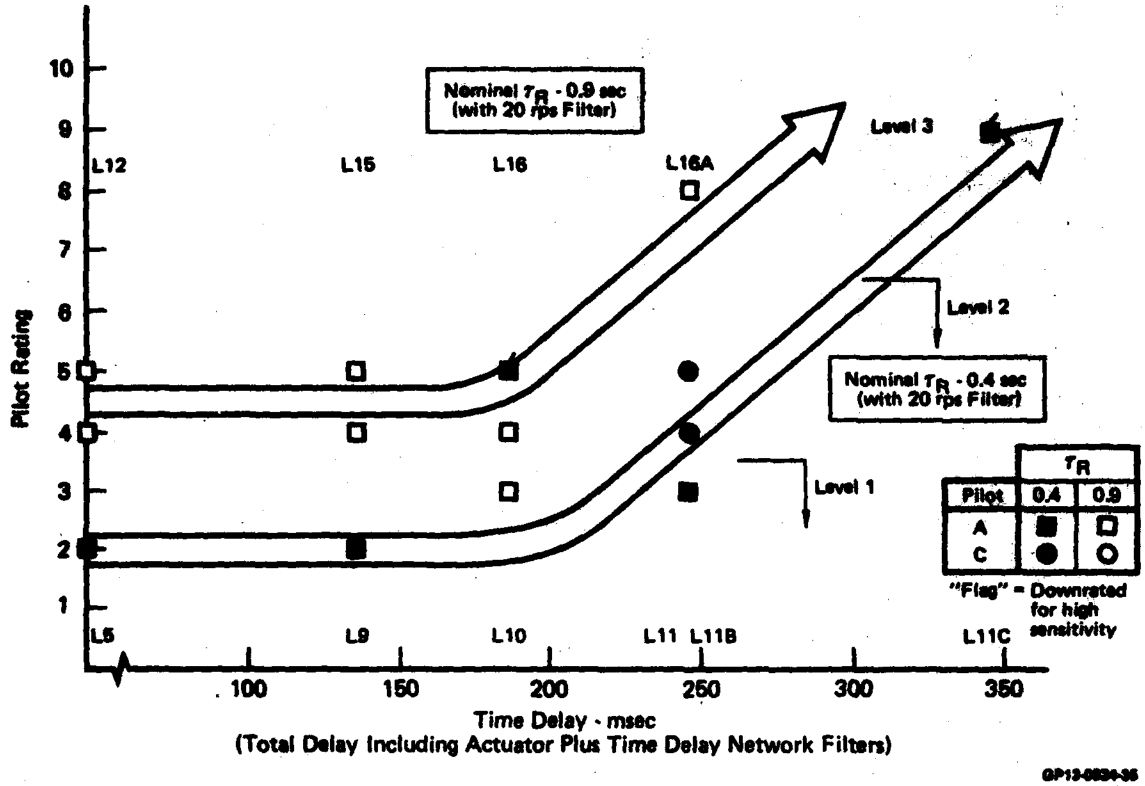
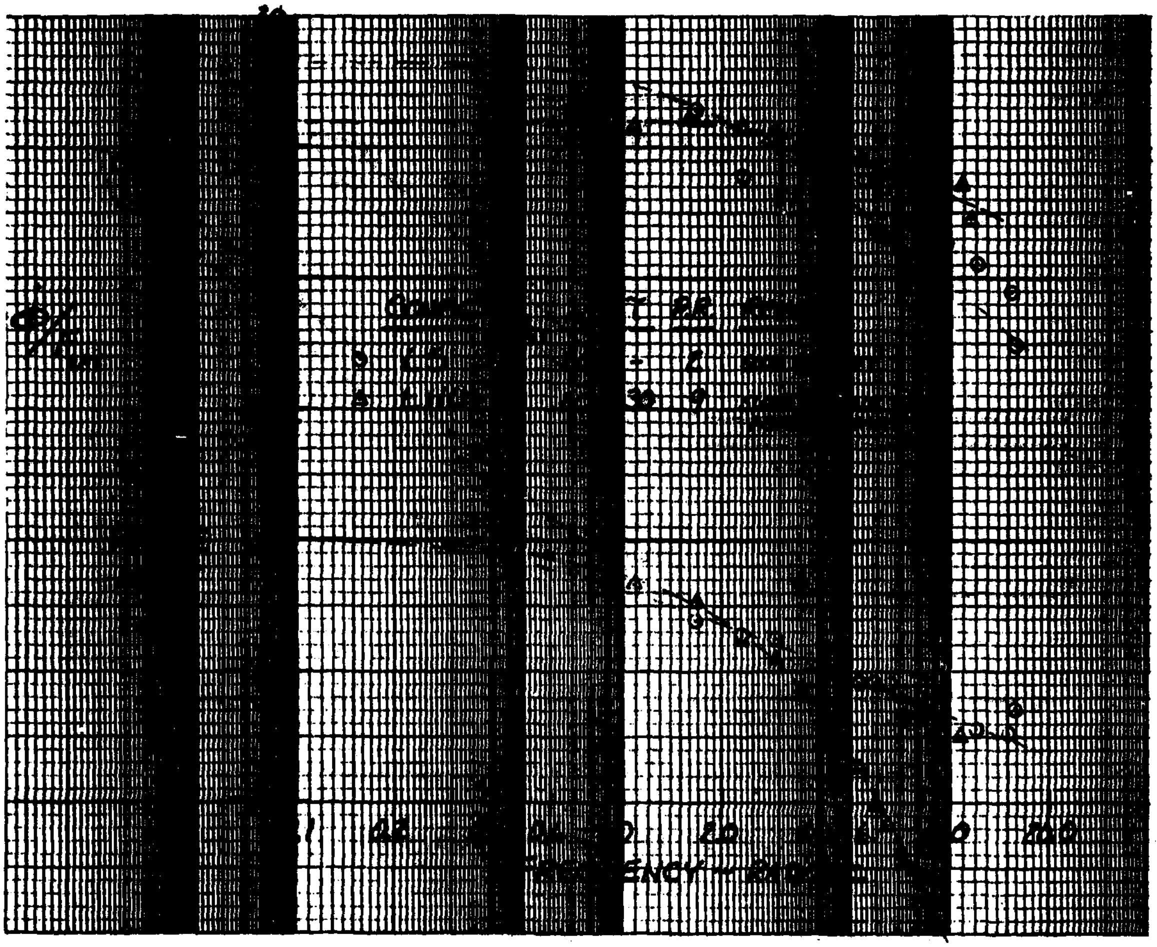


Figure 23. Effect of Time Delay (Roll)

Again, the data is hardly definitive but should serve as a basis for further work. A general comment would be that the tolerance to time delay may be higher for the lateral axis than it is for the longitudinal.

d. <u>Task Observations</u> - The lateral comments indicate that the critical lateral tasks were the sidestep maneuvers which were performed with reference to the real runway. In general, lateral problems were noted higher on the approach (say 100 to 200 ft during the sidesteps) rather than close to the runway (last 50 ft) where the longitudinal problems occurred. Of course, the evaluations were not performed in significant crosswinds and turbulence which would make the final stage of the lateral task more critical.

6. <u>DATA ANALYSIS METHODS</u> - In addition to the in-flight pilot ratings, several techniques have been used in analysis of the the Equivalent Systems Program data. Results from these analyses have been used in the discussions in Sections VI-2 and VI-3, and the detailed analyses are presented in Appendices A through F.



GP13-0004-22

Figure 24. Effect of Time Delay, Frequency Domain

The pilots' comments in Appendices A and B are repeated from the original CALSPAN Report 6241-F-3 (Reference 9). In Appendix C, comparisons of high and low order systems designated as equivalents are plotted in terms of frequency response for the measured test data. The analytical pitch rate response characteristics, as programmed for the test, are presented in Appendix D with the step time history matches for each configurations.

The in-flight time history data for the landing tasks are plotted in Appendix E for a selected group of the configurations. The majority of flights shown are with Pilot A. For each time history a Fast Fourier Transform method of analysis is used to present frequency domain characteristics just prior to touchdown.

The Neal and Smith closed-loop analysis technique was applied to the Equivalent Systems Program data for both longitudinal and lateral sets of dynamics. Results are presented in Appendix F.

SECTION VII

RECOMMENDATIONS

This short in-flight evaluation program to study the validity of the equivalent system concept and the flying qualities effects of additional control system dynamics should be viewed as exploratory. Although the results derived from the program are informative, more data is required to expand and substantiate the results. Specifically, the following recommendations are presented:

(1) The verification test for lateral equivalent systems was inconclusive in this evaluation program. More work is, therefore, required to explore the validity of the lateral equivalent system concept as a flying qualities analysis method for highly augmented fighter aircraft.

(2) The data on the effects of control system dynamics on fighter lateral approach and landing flying qualities gathered in this experiment represents the first step towards building an appropriate data base from which suitable requirements can be derived. More lateral data is required for all critical tasks, including up and away tasks.

(3) While the results of the verification test for longitudinal equivalent systems were encouraging, several peripheral areas require further study. The effects of high frequency gain should be the subject of further careful study; results of such a study would provide a better understanding of the frequency range over which the equivalent system should be constructed.

(4) The effects of time delay on flying qualities is pertinent to today's fighter aircraft with the advent of the digital flight control system. A careful study of the effects of time delay on longitudinal and lateral flying qualities should be undertaken using the results of this experiment as a basis for the experiment. There was some evidence in this program that the desired "control sensitivity" was a function of the time delay present; this effect should be studied in a follow-on experiment. These recommendations also apply to the critical up and away tasks, such as tracking.

(5) Recent in-flight simulation experience in evaluations of the F-18, YF-17, F-16 and Space Shuttle indicates a dramatic difference in the results of flying qualities evaluations for critical tasks performed in ground simulators as opposed to in-flight simulators, such as the NT-33. It would seem appropriate, and technically important, to understand and clarify these differences. A step in that direction would be to repeat some of the evaluations from this experiment on a sophisticated ground simulator. Such an experiment would require very careful preparation, particularly in defining the evaluation tasks and preparing the evaluation pilot.

(6) The addition of pure digital time delay to low-order systems can result in excessive phase lags at high frequencies. Although lead/lag filters will tailor the phase lag at a specific response frequency, it is advisable to be alert for potentially adverse effects of filters on the broadband requirements of piloting tasks which require accurate flight path and/or attitude control.

(7) Although a demanding task for the evaluations serves to give consistent pilot ratings, a skilled pilot inadvertantly may mask poor handling qualities by avoiding the faults of the control configuration and report misleading pilot ratings. Repeat evaluations and/or alternate pilots will help to identify anomalies in ratings due to pilot technique.

(8) The Fast Fourier Transform method of converting time history data to the frequency domain is an efficient technique for response analyses and verification of configuration descriptions in an equivalent systems program.

APPENDIX A

LONGITUDINAL PILOT COMMENTS

Brief summaries of the pertinent pilot comments for the longitudinal evaluation configurations are presented in this Appendix. The heading block information is consistent with the data summary table in Section VI-1. Note that the digit after the flight number represents the order in which the evaluation was performed on that flight.

CONFIGURATION	HOS-1	ω	ζ	λ_D/λ_N	φ_{ss}/lb	DELAY	CARD	FLIGHT
P1	✓							2072-1
PILOT RATING (SP)	LOS	-	-	-/-	0.8	-	-	PILOT
2 (3)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	No comments.
	ANY COMPLAINTS ABOUT - SENSITIVITY?	No
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Teeniest bit of overcontrol on nose but predictable.
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Yes
	ANY TENDENCY TO PIO? OVERCONTROL? -	No
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	No problems.
	LANDING, MOST DIFFICULT? -	Yes, tended to land a bit long.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Flare Okay. Predictable aircraft.	

NOTE: Advanced fighter HOS (45° flap)

CONFIGURATION	HOS-1	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P1	✓							2070-2
PILOT RATING (SP)	LOS	-	-	-	0.8	-	-	PILOT
2 (3)								B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	No problems
	ANY COMPLAINTS ABOUT - SENSITIVITY?	Good
PITCH ATTITUDE RESPONSE TO INPUTS <u>REQUIRED TO PERFORM TASK</u>:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Good
	ANY SPECIAL PILOT INPUTS? -	No
	ANY TENDENCY TOWARDS PIO? -	No, ballooned from gust
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Little bit sensitive laterally
	ANY TENDENCY TO - PIO? OVERCONTROL?	Sidesteps worked out real well - No PIO tendency
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	Good
	LANDING, MOST - DIFFICULT?	Good
EFFECTS OF WIND/TURBULENCE:		No effect
SUMMARY COMMENTS: ANY CHANGE IN RATING?		Negligible deficiencies

NOTE: Advanced fighter HOS (45° flap)

CONFIGURATION	HOS -1	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P1	✓							2068-2
PILOT RATING (SP)	LOS	-	-	-	0.8	-	-	PILOT
3 (3)								C

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	satisfactory, slightly "looser" than first configuration
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no problems except when countering simulated gusts
PITCH ATTITUDE RESPONSE TO INPUTS <u>REQUIRED TO PERFORM TASK</u>:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	very predictable
	ANY SPECIAL PILOT INPUTS? -	none
	ANY TENDENCY TOWARDS PIO? -	none
VELOCITY CONTROL: SATISFACTORY?		no problems
BANK ANGLE CONTROL:	SATISFACTORY? -	yes
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		okay
PERFORMANCE:	APPROACH -	no problems
	LANDING, MOST - DIFFICULT?	yes, but no problem
EFFECTS OF WIND/TURBULENCE:		light, mild X-wind; not a factor
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Rating a 2 to 3.	

NOTE: Advanced fighter HOS (45° flap)

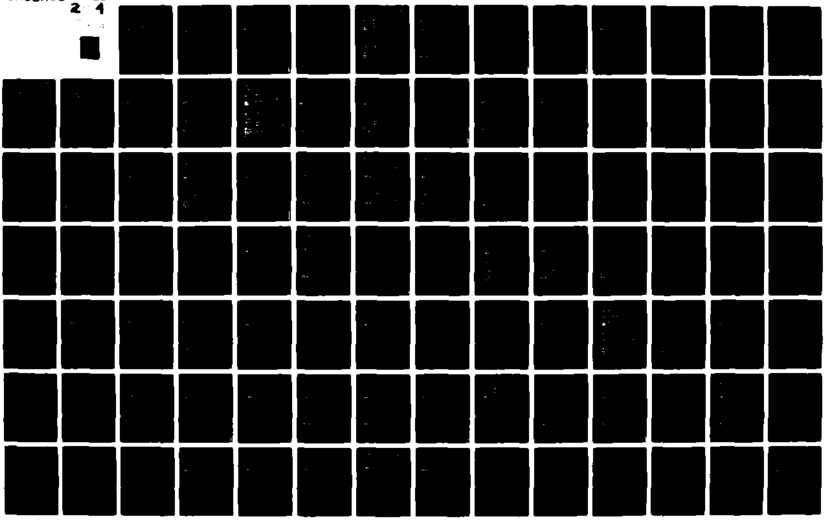
CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P2								2072-3
PILOT RATING (SP)	LOS ✓	1.5	1.1	0.7/0.5	0.6	.12	-	PILOT
2 (3)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	Fine
	ANY COMPLAINTS ABOUT - SENSITIVITY?	When slow after landing longitudinal sensitivity low.
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Normal initial response Okay, predictable final response.
	ANY SPECIAL PILOT INPUTS? -	No problems
	ANY TENDENCY TOWARDS PIO? -	Little bit of overcontrol at touchdown, stick forces felt a little heavy.
VELOCITY CONTROL: SATISFACTORY?		Yes
BANK ANGLE CONTROL:	SATISFACTORY? -	Yes
	ANY TENDENCY TO - PIO? OVERCONTROL?	No
TURN COORDINATION: A PROBLEM?		No problem.
PERFORMANCE:	APPROACH -	No problems.
	LANDING, MOST - DIFFICULT?	Heavy longitudinal forces in last bit of flare and touchdown.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Nothing to add.	

NOTE: ES for P1, L_α Fixed

AD-A119 704 CALSPAN CORP BUFFALO NY FLIGHT RESEARCH DEPT F/G 1/2
EQUIVALENT SYSTEM VERIFICATION AND EVALUATION OF AUGMENTATION E--ETC(U)
SEP 81 R E SMITH, J HODGKINSON, R C SNYDER F33615-78-C-3602
UNCLASSIFIED CALSPAN-6241-F-3-VOL-2 AFWAL-TR-81-3116-VOL-2 NL

2 4



CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P2A								2060-4
PILOT RATING (SP)	LOS	1.6	0,8	0.7/0.5	1.0	.12	-	PILOT
4 (4)	✓							C

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY? ANY COMPLAINTS ABOUT - SENSITIVITY?	lateral- okay but too sensitive longitudinal - too much sensitivity
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE - ANY SPECIAL PILOT INPUTS? - ANY TENDENCY TOWARDS PIO? -	over sensitive had to keep my inputs small slight tendency to PIO
VELOCITY CONTROL: SATISFACTORY?		satisfactory
BANK ANGLE CONTROL:	SATISFACTORY? - ANY TENDENCY TO - PIO? OVERCONTROL?	satisfactory no
TURN COORDINATION: A PROBLEM?		satisfactory
PERFORMANCE:	APPROACH - LANDING, MOST - DIFFICULT?	sensitivity didn't show up in approach yes, because of sensitivity problem
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Could do job but too sensitive in pitch. No tendency to overcontrol after touchdown as in previous configurations.	

NOTE: ES for P1, L_α Fixed

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P3								2073-4
PILOT RATING (SP)	LOS	2.6	0.6	0.7/6.3	0.6	.07	I	PILOT
3 (3)	✓							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	Okay slightly heavy longitudinally in flare.
	ANY COMPLAINTS ABOUT - SENSITIVITY?	No
PITCH ATTITUDE RESPONSE TO INPUTS <u>REQUIRED TO PERFORM TASK</u>:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Little lag tended slight overcontrol.
	ANY SPECIAL PILOT INPUTS? -	Little tendency to put input in then wait.
	ANY TENDENCY TOWARDS PIO? -	No
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Okay
	ANY TENDENCY TO - PIO? OVERCONTROL?	Okay
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	Piece of cake.
	LANDING, MOST - DIFFICULT?	Little overcontrol in flare and lift off.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	No comments.	

NOTE: Reduced gain L_α free equivalent of P1

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P3A		2.6	0.6	0.7/6.3	0.9	.07	I	2070-4
PILOT RATING (SP)	LOS							PILOT
3 (3)	✓							8

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	Okay at first.
	ANY COMPLAINTS ABOUT - SENSITIVITY?	Not too bad longitudinally.
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Okay
	ANY SPECIAL PILOT INPUTS? -	No
	ANY TENDENCY TOWARDS PIO? -	Tendency to overcontrol in flare.
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	No complaints.
	ANY TENDENCY TO PIO? OVERCONTROL? -	No
TURN COORDINATION: A PROBLEM?		No problem.
PERFORMANCE:	APPROACH -	Okay
	LANDING, MOST DIFFICULT? -	Okay
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?		No comments.

NOTE: Increased gain L_α free equivalent of P1

CONFIGURATION	HOS-2	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P4	✓							2071-1
PILOT RATING (SP)	LOS	-	-	-	1.3	-	-	PILOT
3 (3)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	No comments
	ANY COMPLAINTS ABOUT - SENSITIVITY?	No
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Little bit of overcontrol due to lag in flare.
	ANY SPECIAL PILOT INPUTS? -	No
	ANY TENDENCY TOWARDS PIO? -	No
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Yes
	ANY TENDENCY TO - PIO? OVERCONTROL?	No
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	No problems.
	LANDING, MOST - DIFFICULT?	Yes, slight overcontrol.
EFFECTS OF WIND/TURBULENCE:		
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Nice until flare then noticed lag. Slight overcontrol	

NOTE: Advanced Fighter HOS (30° flap)

CONFIGURATION	HOS-2	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P4	✓							2073-1
PILOT RATING (SP)	LOS	-	-	-	1.3	-	-	PILOT
4 (3)								B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	No comments
	ANY COMPLAINTS ABOUT - SENSITIVITY?	Little more sensitive pitch and roll than seen before.
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Tendency to overcontrol due to sensitivity, got better with exposure.
	ANY SPECIAL PILOT INPUTS? -	No
	ANY TENDENCY TOWARDS PIO? -	No
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Okay
	ANY TENDENCY TO - PIO? OVERCONTROL?	Okay
TURN COORDINATION: A PROBLEM?		No problem.
PERFORMANCE:	APPROACH -	Little easier.
	LANDING, MOST - DIFFICULT?	Yes, but no real problems.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Worked hard in flare, landed long first time or two.	

NOTE: Advanced Fighter HOS (30° flap)

CONFIGURATION	HOS-2	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P4	✓							2073-9
PILOT RATING (SP)	LOS	-	-	-/-	1.3	-	-	PILOT
3 (3)								B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	Okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	Okay
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Little difficult to establish initial pitch attitude, worked fairly hard.
	ANY SPECIAL PILOT INPUTS? -	No.
	ANY TENDENCY TOWARDS PIO? -	No.
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Okay
	ANY TENDENCY TO - PIO? OVERCONTROL?	
TURN COORDINATION: A PROBLEM?		No problem
PERFORMANCE:	APPROACH -	Pretty good.
	LANDING, MOST - DIFFICULT?	Little worse but not bad.
EFFECTS OF WIND/TURBULENCE:		
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Saw a little "hunting" in pitch but a minor problem.	

NOTE: Advanced Fighter HOS (30° flap)

CONFIGURATION	HOS-2	ω	ζ	λ_p/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P4A	✓							2071-7
PILOT RATING (SP)	LOS	-	-	-/-	1.1	-	-	PILOT
2 (3)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	No comments.
	ANY COMPLAINTS ABOUT - SENSITIVITY?	No
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Tiniest bit of lag and over control of nose.
	ANY SPECIAL PILOT INPUTS? -	No
	ANY TENDENCY TOWARDS PIO? -	No tendency to PIO.
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Yes
	ANY TENDENCY TO - PIO? OVERCONTROL?	No
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	Okay
	LANDING, MOST - DIFFICULT?	no problem.
EFFECTS OF WIND/TURBULENCE:		None, very calm air.
SUMMARY COMMENTS: ANY CHANGE IN RATING?	One of best flown so far very predictable. Rating 2 to 3.	

NOTE: P4 with reduced gain. Only 1 landing performed.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
PS								2071-3
PILOT RATING (SP)	LOS	1.9	1.4	0.7/0.55	1.1	.12	-	PILOT
6 (6)	✓							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	Slightly heavy longitudinally.
	ANY COMPLAINTS ABOUT - SENSITIVITY?	Okay
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Overcontrolled final response, quick response.
	ANY SPECIAL PILOT INPUTS? -	No
	ANY TENDENCY TOWARDS PIO? -	Small oscillations in flare and touchdown, small amplitude PIO.
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Okay
	ANY TENDENCY TO - PIO? OVERCONTROL?	No
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	No Problem
	LANDING, MOST - DIFFICULT?	Yes, small, quick oscillation in flare.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Quick inputs caused PIO's. Nice airplane until quick inputs applied. Good if satisfied with a landing 500' long.	

NOTE: ES for P4, L_α fixed.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P5								2073-3
PILOT RATING (SP)	LOS	1.9	1.4	0.7/0.55	1.0	.12	-	PILOT
6 (5)	✓							B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	Okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	Longitudinal was too sensitive.
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Not getting what I wanted or when.
	ANY SPECIAL PILOT INPUTS? -	Yes, careful attention required, had to lower gain.
	ANY TENDENCY TOWARDS PIO? -	No, but worked stick hard to avoid.
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Yes
	ANY TENDENCY TO PIO? OVERCONTROL? -	Banking set up bobble in pitch axis.
TURN COORDINATION: A PROBLEM?		Not a problem.
PERFORMANCE:	APPROACH -	Much better than landing.
	LANDING, MOST DIFFICULT? -	Yes
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Borders on a 7.	

NOTE: ES for P4, L_α fixed

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
PSA	✓							2073-8
PILOT RATING (SP)	LOS	1.9	1.4	8/-	0.4	-	-	PILOT
7 (6)								B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	Not satisfactory, pitch heavy, slow, lacks harmony.
	ANY COMPLAINTS ABOUT - SENSITIVITY?	
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Slow, but predictable
	ANY SPECIAL PILOT INPUTS? -	"Milk" it along start input early, don't overdrive it.
	ANY TENDENCY TOWARDS PIO? -	NO
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	No problem.
	ANY TENDENCY TO PIO? OVERCONTROL? -	
TURN COORDINATION: A PROBLEM?		No problem.
PERFORMANCE:	APPROACH -	Not all that good either.
	LANDING, MOST DIFFICULT? -	Yes
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	No change in rating (sensitivity set incorrectly).	

NOTE: ES for P4, but with very low sensitivity.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P5B								2086-4
PILOT RATING (SP)	LOS	1.9	1.4	0.7/0.55	0.7	.12	-	PILOT
3 (3)	✓							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	Okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	No
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Slight hesitation and tendency to overcontrol.
	ANY SPECIAL PILOT INPUTS? -	Had to put input in and wa'
	ANY TENDENCY TOWARDS PIO? -	No
VELOCITY CONTROL: SATISFACTORY?		Ok
BANK ANGLE CONTROL:	SATISFACTORY? -	No problem.
	ANY TENDENCY TO PIO? OVERCONTROL? -	No
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	Good
	LANDING, MOST DIFFICULT? -	Yes, could overcontrol nose in flare - minor problem.
EFFECTS OF WIND/TURBULENCE:		No comments.
SUMMARY COMMENTS: ANY CHANGE IN RATING?		

NOTE: P5 with reduced gain.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P5B								2073-4
PILOT RATING (SP)	LOS	1.9	1.4	0.7/0.5S	0.7	.12	-	PILOT
2 (2)	✓							B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	No comments.
	ANY COMPLAINTS ABOUT - SENSITIVITY?	No comments.
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Negligible deficiencies.
	ANY SPECIAL PILOT INPUTS? -	No
	ANY TENDENCY TOWARDS PIO? -	No
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Yes
	ANY TENDENCY TO - PIO? OVERCONTROL?	No
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	No problems.
	LANDING, MOST - DIFFICULT?	No problem.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Negligible deficiencies (only one landing).	

NOTE: *P5 with reduced gain.*

CONFIGURATION	NOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
PSC								2086-3
PILOT RATING (SP)	LOS	1.9	1.4	-/-	0.7	.12	-	PILOT
2 (3)	✓							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	Fine
	ANY COMPLAINTS ABOUT - SENSITIVITY?	No comments.
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Initial response was sure, final was Okay. Little more sluggish than desired.
	ANY SPECIAL PILOT INPUTS? -	No
	ANY TENDENCY TOWARDS PIO? -	No
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Okay
	ANY TENDENCY TO - PIO? OVERCONTROL?	No
TURN COORDINATION: A PROBLEM?		No
PERFORMANCE:	APPROACH -	No problem
	LANDING, MOST - DIFFICULT?	For perfection could have been just a little quicker in pitch.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Good aircraft.	

Note: Modified ES for P4

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P6								2071-4
PILOT RATING (SP)	LOS	2.6	0.6	0.7/12.5	1.1	.06	III	PILOT
4 (5)	✓							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	Okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	No
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Little bit of lag then bit of overcontrol.
	ANY SPECIAL PILOT INPUTS? -	No
	ANY TENDENCY TOWARDS PIO? -	Not really noticed.
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Yes
	ANY TENDENCY TO PIO? OVERCONTROL? -	No
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	Very easy
	LANDING, MOST DIFFICULT? -	Yes, easy if landed long.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?		Wouldn't get PIO if you let it land 500 ft long.

NOTE: ES for P4, L_α free.

CONFIGURATION	HOS	ω	ζ	"D'/"N	ϕ_{SS}/[illegible]	[illegible]	[illegible]	[illegible]
P6								2073-5
PILOT RATING (SP)	LOS	2.6	0.6	0.7/12.5	1.1	.14	III	PILOT
4 (3)	✓							B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	No comments
	ANY COMPLAINTS ABOUT - SENSITIVITY?	Sensitive nose, took a very light hand on stick in pitch and roll.
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Predictable but sensitive.
	ANY SPECIAL PILOT INPUTS? -	No
	ANY TENDENCY TOWARDS PIO? -	None
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Yes, no problem.
	ANY TENDENCY TO - PIO? OVERCONTROL?	No
TURN COORDINATION: A PROBLEM?		No problem.
PERFORMANCE:	APPROACH -	Okay
	LANDING, MOST - DIFFICULT?	Not much difference.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	No change in rating.	

NOTE: ES for P4, L_α free.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P7	✓							2062-3
PILOT RATING (SP)	LOS	2.3	1.1	4/-	0.8	-	-	PILOT
4 (3)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	Okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	slow initial response, overcontrolled final
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	no steady PIO
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Okay
	ANY TENDENCY TO PIO? OVERCONTROL? -	no
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	no problem
	LANDING, MOST DIFFICULT? -	yes, overcontrol in flare a little
EFFECTS OF WIND/TURBULENCE:		no comments
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Straight in okay. Overcontrol in flare. Wanted to put in small input and see what resulted, didn't do it and was overcontrolling a little.	

NOTE: HOS - LAHOS Config. 4-3, Force Commands.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P7	✓							2071-2
PILOT RATING (SP)	LOS	2.3	1.1	4/-	0.8	-	-	PILOT
2 (3)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	No comments
	ANY COMPLAINTS ABOUT - SENSITIVITY?	Slightest bit sluggish (longitudinally) Nose a bit quicker than was in previous configuration (P4A).
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Didn't see much delay in nose
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Fine
	ANY TENDENCY TO - PIO? OVERCONTROL?	No
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	No problem
	LANDING, MOST - DIFFICULT?	More positive control of the nose than in the previous configuration (P4A)
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Little bit better than last one (P4A). Very good, rating 1 to 2.	

NOTE: HOS - LAHOS Config. 4-3, Force Commands.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P7	✓							2063-3
PILOT RATING (SP)	LOS	2.3	1.1	4/-	0.8	-	-	PILOT
4 (3)								B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	not too bad
	ANY COMPLAINTS ABOUT - SENSITIVITY?	too much pitch axis sensitivity
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	tendency to overcontrol pitch corrections; grosser moments no problem
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	no
VELOCITY CONTROL: SATISFACTORY?		no problem
BANK ANGLE CONTROL:	SATISFACTORY? -	no problem
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	better than landing
	LANDING, MOST - DIFFICULT?	yes
EFFECTS OF WIND/TURBULENCE:		wind/turbulence not a factor
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Little too sensitive. Tendency to overcontrol, correction from simulated gusts got good results. Gross movements no problem, minor but annoying deficiencies.	

NOTE: HOS - LAHOS Config. 4-3, Force Commands.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P8								2071-S
PILOT RATING (SP)	LOS ✓	1.6	0.8	-/-	0.8	.10	-	PILOT
5 (5)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	Little heavy longitudinally.
	ANY COMPLAINTS ABOUT - SENSITIVITY?	
PITCH ATTITUDE RESPONSE TO INPUTS <u>REQUIRED TO</u> <u>PERFORM TASK:</u>	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Overcontrol on final response Little bit slow on initial Response.
	ANY SPECIAL PILOT INPUTS? -	After input, wait to see what I've got.
	ANY TENDENCY TOWARDS PIO? -	No PIO.
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Yes
	ANY TENDENCY TO - PIO? OVERCONTROL?	No
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	No comment
	LANDING, MOST - DIFFICULT?	
EFFECTS OF WIND/TURBULENCE:		
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Rating 4 to 5, selected 5.	

NOTE: ES for P7, L_α fixed.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P8								2069-2
PILOT RATING (SP)	LOS	1.6	0.8	-/-	0.8	.10	-	PILOT
5 (5)	✓							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no problem
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	bit of lag in initial response and overcontrol on final response
	ANY SPECIAL PILOT INPUTS? -	had to back out of loop a bit and put in smaller input
	ANY TENDENCY TOWARDS PIO? -	overcontrol in flare
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	little bit of lateral sensitivity
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		okay
PERFORMANCE:	APPROACH -	real sweet until flare
	LANDING, MOST - DIFFICULT?	only problem was a little pitch overcontrol in flare, also bank angle
EFFECTS OF WIND/TURBULENCE:		not a factor
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Overcontrolling nose a bit in flare, possibly a 4.	

NOTE: ES for P7, L_α fixed.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P9								2069-3
PILOT RATING (SP)	LOS	2.6	0.6	0.7/-	0.9	-	II	PILOT
3 (4)	✓							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	no comments
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no comments
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	overcontrolled a little in flare pretty good
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	no
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	no comments
	ANY TENDENCY TO - PIO? OVERCONTROL?	no --
TURN COORDINATION: A PROBLEM?		not a problem
PERFORMANCE:	APPROACH -	okay
	LANDING, MOST - DIFFICULT?	yes, but no problem
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Slight overcontrolling tendency in flare but a pretty good airplane.	

NOTE: ES for P7, L_α free.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P10								2062-1
PILOT RATING (SP)	LOS ✓	2.6	0.6	-/-	0.4	-	-	PILOT
3 (2)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	light
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	tendency to overcontrol in flare
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	no
VELOCITY CONTROL: SATISFACTORY?		no problem
BANK ANGLE CONTROL:	SATISFACTORY? -	no problem
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	piece of cake
	LANDING, MOST - DIFFICULT?	yes, bit of overcontrol of nose in final flare
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Tendency to overcontrol (Longitudinal), when making quick flare in close. Very good airplane but for more difficult task (side-step), would have liked more longitudinal predictability.	

NOTE: LAHOS 2-1, Force Commands.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P10								2063-1
PILOT RATING (SP)	LOS	2.6	0.6	-/-	0.4	-	-	PILOT
2 (1)	✓							B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	little mushy around center
	ANY COMPLAINTS ABOUT - SENSITIVITY?	quite sensitive
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	very predictable
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	no
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	no problem
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	no problem
	LANDING, MOST - DIFFICULT?	no problem - little x-wind but no trouble
EFFECTS OF WIND/TURBULENCE:		bit of bobble in response to simulated gusts
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Negligible deficiencies (Safety Pilot comment: pilot is very smooth and good at predicting required inputs)	

NOTE: LAHOS 2-1, Force Commands.

CONFIGURATION	NOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P10								2068-1
PILOT RATING (SP)	LOS	2.6	0.6	-/-	0.4	-	-	PILOT
2 (2)	✓							C

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	very light
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	very responsive but no bobble
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	none
VELOCITY CONTROL: SATISFACTORY?		very good; able to maintain desired angle of attack
BANK ANGLE CONTROL:	SATISFACTORY? -	no tendency to overshoot
	ANY TENDENCY TO - PIO? OVERCONTROL?	no PIO
TURN COORDINATION: A PROBLEM?		no requirement to use rudders
PERFORMANCE:	APPROACH -	easy
	LANDING, MOST - DIFFICULT?	more difficult
EFFECTS OF WIND/TURBULENCE:		very light turbulence but not a factor
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Very nice machine.	

NOTE: LAHOS 2-1, Force Commands.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P10A								2069-5
PILOT RATING (SP)	LOS	2.6	0.6	-/-	0.4	.05	-	PILOT
3 (2)	✓							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	no problem
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no comments
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	very little lag in longitudinal
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	no
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	yes
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		okay
PERFORMANCE:	APPROACH -	no problem
	LANDING, MOST - DIFFICULT?	yes, slight bit of over-control in flare
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Little bit of lag in pitch. Debate is between 2 and 3. Little bit of overcontrol. Close to an ideal airplane.	

NOTE: P10 plus feel system delay.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P10B								2071-6
PILOT RATING (SP)	LOS ✓	2.6	0.6	-/-	0.4	.10	-	PILOT
3 (3)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY? ANY COMPLAINTS ABOUT - SENSITIVITY?	Longitudinal forces seem higher than last one (P8) I'm getting a little tired).
PITCH ATTITUDE RESPONSE TO INPUTS <u>REQUIRED TO PERFORM TASK</u>:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE - ANY SPECIAL PILOT INPUTS? - ANY TENDENCY TOWARDS PIO? -	Not as much lag as last (P8) started to move then got too much. No No
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? - ANY TENDENCY TO - PIO? OVERCONTROL?	Yes No
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH - LANDING, MOST - DIFFICULT?	Okay Yes, noticed higher longitudinal forces.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	No problem until flare, then the problem (minor) was heavy forces in pitch.	

NOTE: P10 plus time delay.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P10B		2.6	0.6	-/-	0.4	.10	-	2070-1
PILOT RATING (SP)	LOS							PILOT
2 (2)	✓							B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	free play in the stick - sloppiness in both axes
	ANY COMPLAINTS ABOUT - SENSITIVITY?	sensitive both in pitch and roll
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no comments
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	no
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	yes
	ANY TENDENCY TO PIO? OVERCONTROL? -	no
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	no problems
	LANDING, MOST DIFFICULT? -	yes, did not do well on touchdown point
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Didn't do very well on touchdown point (poor selection of initial aimpoint) otherwise airplane was a 2. Varied between 2 and 3. (Safety Pilot comment: very smooth, adaptive pilot).	

NOTE: P10 plus time delay.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P10C								2072-5
PILOT RATING (SP)	LOS	2.6	0.6	-/-	0.4	.13	-	PILOT
4 (5)	✓							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	Okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	Okay
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Little slow initial response and slight overcontrol.
	ANY SPECIAL PILOT INPUTS? -	Felt I might start PIO if I upped my gain any. Used slow inputs.
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Okay
	ANY TENDENCY TO - PIO? OVERCONTROL?	
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	No problem.
	LANDING, MOST - DIFFICULT?	Yes, felt a little sluggish
EFFECTS OF WIND/TURBULENCE:		Not a factor.
SUMMARY COMMENTS: ANY CHANGE IN RATING?	It flew pretty much as I want it to, no major problems.	

NOTE: P10 plus time delay.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P10D								2086-5
PILOT RATING (SP)	LOS	2.6	0.6	-/-	0.4	.20	-	PILOT
7 (7)	✓							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	No comments
	ANY COMPLAINTS ABOUT - SENSITIVITY?	No
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Slow, tended to overcontrol, not predictable.
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	Yes, in flare. Possibly not PIO.
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Yes
	ANY TENDENCY TO PIO? OVERCONTROL? -	No
TURN COORDINATION: A PROBLEM?		Not a factor.
PERFORMANCE:	APPROACH -	No problems
	LANDING, MOST DIFFICULT? -	Yes tended to overcontrol in flare, small PIO.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	No change.	

NOTE: P10 plus time delay.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P10D								2073-7
PILOT RATING (SP)	LOS	2.6	0.6	-/-	0.4	.20	-	PILOT
3 (4)	✓							B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	Okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	No.
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Had to wait to see effect of input "little hunting".
	ANY SPECIAL PILOT INPUTS? -	No
	ANY TENDENCY TOWARDS PIO? -	No
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Yes
	ANY TENDENCY TO PIO? OVERCONTROL? -	No
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	Good
	LANDING, MOST DIFFICULT? -	Little worse but not bad.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Little longitudinal problem but minor. Response delayed.	

NOTE: P10 plus time delay.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P10D								2070-6
PILOT RATING (SP)	LOS	2.6	0.6	-/-	0.4	.20	-	PILOT
8 (7)	✓							B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	Little heavy initially but not the same kind of sensitivity as seen before.
	ANY COMPLAINTS ABOUT - SENSITIVITY?	No comments.
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	A problem: not predictable
	ANY SPECIAL PILOT INPUTS? -	A lot of corrections needed to maintain control.
	ANY TENDENCY TOWARDS PIO? -	Not PIO but jerky.
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Okay
	ANY TENDENCY TO - PIO? OVERCONTROL?	Okay
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	No comments.
	LANDING, MOST - DIFFICULT?	Problem is in the flare.
EFFECTS OF WIND/TURBULENCE:		No effects.
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Little longitudinal bobble in flare, rating 8 to 9.	

NOTE: P10 plus time delay.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	q_{ss}/lb	DELAY	CARD	FLIGHT
P11	✓							2062-2
PILOT RATING (SP)	LOS	2.6	0.6	-/-	0.4	-	IV	PILOT
6 (6)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	no problems
	ANY COMPLAINTS ABOUT - SENSITIVITY?	
PITCH ATTITUDE RESPONSE TO INPUTS <u>REQUIRED TO PERFORM TASK</u>:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	tendency to overcontrol for large offset, when I tried to work the nose
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	Got a small PIO: stayed in loop and was able to stay in control
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	no problem
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	piece of cake
	LANDING, MOST - DIFFICULT? -	yes
EFFECTS OF WIND/TURBULENCE:		no factor
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Straight in no problem. Mild oscillation in flare (Maybe a 5)	

NOTE: HOS - LAHOS Config. 2-11, Force Commands.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P11	✓							2063-2
PILOT RATING (SP)	LOS	2.6	0.6	-/-	0.4	-	IV	PILOT
4 (4)								B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY? ANY COMPLAINTS ABOUT - SENSITIVITY?	about same as first configuration (P10) saw lag on downwind and in landing with simulated gusts. some sloppiness in piech
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	worked hard
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	no
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	no problem
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	no problem
	LANDING, MOST - DIFFICULT?	yes, touchdown point not good in spite of working hard
EFFECTS OF WIND/TURBULENCE:		control of simulated gusts required quite a bit more work
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Worked hard longitudinally, aircraft was annoying in pitch.	

NOTE: HOS - LAHOS Config. 2-11, Force Commands.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P11A	✓							2086-2
PILOT RATING (SP)	LOS	2.6	0.6	-/-	0.4	.05	IV	PILOT
7 (8)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	No problems.
	ANY COMPLAINTS ABOUT - SENSITIVITY?	No comments.
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Initial response sluggish
	ANY SPECIAL PILOT INPUTS? -	No
	ANY TENDENCY TOWARDS PIO? -	Pitch bobble in flare, some PIO tendency.
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Okay
	ANY TENDENCY TO - PIO? OVERCONTROL?	No
TURN COORDINATION: A PROBLEM?		Not a factor
PERFORMANCE:	APPROACH -	No problem
	LANDING, MOST - DIFFICULT?	Yes, holding pitch attitude especially in flare and rollout was main problem.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	No changes.	

NOTE: HOS P11 plus feel systems delay.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P11A	✓							2062-5
PILOT RATING (SP)	LOS	2.6	0.6	-/-	0.4	.05	IV	PILOT
6 (7)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	little bit heavy
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	oscillating a bit
	ANY SPECIAL PILOT INPUTS? -	aircraft was so slow I could get back in loop and drive it.
	ANY TENDENCY TOWARDS PIO? -	little bit
VELOCITY CONTROL: SATISFACTORY?		no comments
BANK ANGLE CONTROL:	SATISFACTORY? -	no problems
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no problems
PERFORMANCE:	APPROACH -	Okay
	LANDING, MOST - DIFFICULT?	yes
EFFECTS OF WIND/TURBULENCE:		no problem
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Very sluggish longitudinally. Would start to move and would overcontrol it, but aircraft was so slow could catch it and stay in the loop. Lack of precision in holding desired nose position was a problem.	

NOTE: HOS P11 plus feel system delay.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P12								2069-1
PILOT RATING (SP)	LOS	2.6	0.6	-/-	0.4	.17	-	PILOT
9 (9)	✓							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	little heavy
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no comments
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problem until flare
	ANY SPECIAL PILOT INPUTS? -	yes, back out of loop to land, fairly high frequency over-control-up into air and back down
	ANY TENDENCY TOWARDS PIO? -	yes, when attempting to land on spot
VELOCITY CONTROL: SATISFACTORY?		no problem
BANK ANGLE CONTROL:	SATISFACTORY? -	no problem
	ANY TENDENCY TO PIO? OVERCONTROL? -	no
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	okay
	LANDING, MOST DIFFICULT? -	yes, a definite problem
EFFECTS OF WIND/TURBULENCE:		no problem
SUMMARY COMMENTS: ANY CHANGE IN RATING?	If it is possible to get lined up or long straight in, could have nursed the aircraft down pretty easily. With large sidestep was definitely driving it into a pretty good PIO.	

NOTE: ES for P11, L_α fixed.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P12								2062-4
PILOT RATING (SP)	LOS	2.6	0.6	-/-	0.4	.17	-	PILOT
7 (6)	✓							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	no problems
	ANY COMPLAINTS ABOUT - SENSITIVITY?	
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	initially slow, was over-controlling final attitude response quite a bit, particularly for large offset.
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	slow PIO, small amplitude, able to stay with it
VELOCITY CONTROL: SATISFACTORY?		no problem
BANK ANGLE CONTROL:	SATISFACTORY? -	no problem
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	no problem
	LANDING, MOST - DIFFICULT?	
EFFECTS OF WIND/TURBULENCE:		no problem
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Was able to stay in loop and touch down reasonably well, but was totally unsatisfactory to stay in there and fly to touchdown. Oscillations were slow.	

NOTE: ES for P11, L_α fixed.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{SS}/lb	DELAY	CARD	FLIGHT
P12		2.6	0.6	-/-	0.4	.17	-	2073-2
PILOT RATING (SP)	LOS							PILOT
5 (8)	✓							B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	Okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	All right no complaints.
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Little bobble in pitch.
	ANY SPECIAL PILOT INPUTS? -	Had to watch inputs.
	ANY TENDENCY TOWARDS PIO? -	No
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	"Hunting" a little in roll.
	ANY TENDENCY TO PIO? OVERCONTROL? -	
TURN COORDINATION: A PROBLEM?		No problem.
PERFORMANCE:	APPROACH -	Little better than landing.
	LANDING, MOST DIFFICULT? -	Yes
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Safety pilot comment: made 4 landings, on the second he over-controlled into a semi-stall in flare, blamed himself but he was really forced into aggressive inputs and nearly lost it.	

NOTE: FS for P11, L_α fixed.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P12								2063-4
PILOT RATING (SP)	LOS ✓	2.6	0.6	-/-	0.4	.17	-	PILOT
7 (6)								B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	
	ANY COMPLAINTS ABOUT - SENSITIVITY?	both axes sensitive.
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	pitch attitude got me in trouble - bobbled off a lateral correction, rairly sensitive
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	bobbled in pitch after lateral correction
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	could get what I wanted
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	considerably worse than approach
	LANDING, MOST - DIFFICULT?	
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Bobble at end of flare.	

NOTE. ES for P11, L_α fixed.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P12A	✓							2069-4
PILOT RATING (SP'	LOS	2.6	0.6	6/2	0.4	.17	-	PILOT
10 (10)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	no problem
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no comments
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	bit of a lag then aircraft would rapidly respond giving low amplitude high frequency oscillation - could not damp it out
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	
	ANY TENDENCY TO - PIO? OVERCONTROL?	okay
TURN COORDINATION: A PROBLEM?		okay
PERFORMANCE:	APPROACH -	no problems
	LANDING, MOST - DIFFICULT?	yes, clearly a major problem
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Could not damp out. PIO in flare. May have been a little divergent. Was worried about losing control when trying to put nose where wanted on ground. Problems in flare.	

NOTE: P12 with $\frac{S+2}{S+5}$ filter added.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P12B	✓	2.6	0.6	20/10	0.9	.17	-	2072-6
PILOT RATING (SP)	LOS							PILOT
9 (8)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	No problem.
	ANY COMPLAINTS ABOUT - SENSITIVITY?	Oversensitive in pitch.
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Too quick initially, unpredictable.
	ANY SPECIAL PILOT INPUTS? -	Small smooth inputs required.
	ANY TENDENCY TOWARDS PIO? -	High frequency PIO evident in all phases of task.
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? - ANY TENDENCY TO - PIO? OVERCONTROL?	Okay
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	Degraded because of sensitive pitch control.
	LANDING, MOST - DIFFICULT?	Yes, not certain I was going to accomplish it correctly. High frequency moderate amplitude PIO in pitch.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Note: system noisy but this deficiency ignored.	

NOTE: P12 with $\frac{S + 10}{S + 20}$ filter added.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	φ_{ss}/lb	DELAY	CARD	FLIGHT
P12C	✓							2072-7
PILOT RATING (SP)	LOS	2.6	0.6	20/10	0.5	.17	-	PILOT
S (S)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	Okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Lag noticedin flare and overcontrol.
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	Small tendency to PIO in flare.
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Yes
	ANY TENDENCY TO PIO? OVERCONTROL? -	No
TURN COORDINATION: A PROBLEM?		No
PERFORMANCE:	APPROACH -	No problem at all.
	LANDING, MOST DIFFICULT? -	Yes, just prior to touchdown got into small amplitude PIO.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Mostly annoying characteristics, could do task (only one landing accomplished).	

NOTE: P12B with gain changed.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P12D	✓							2086-1
PILOT RATING (SP)	LOS	2.6	0.6	6/2	0.2	.17	-	PILOT
8 (8)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	No comments.
	ANY COMPLAINTS ABOUT - SENSITIVITY?	No comments.
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Little lag initially, over-controlled final response.
	ANY SPECIAL PILOT INPUTS? -	No
	ANY TENDENCY TOWARDS PIO? -	Yes, on the runway.
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Okay
	ANY TENDENCY TO - PIO? OVERCONTROL?	
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	Little longitudinal over-control.
	LANDING, MOST - DIFFICULT?	Yes, easy to overcontrol. "Backed out"; to keep from PIO during roll out on the runway.
EFFECTS OF WIND/TURBULENCE:		None.
SUMMARY COMMENTS: ANY CHANGE IN RATING?	No changes.	

NOTE: P12A with gain changed.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P12D	✓							2073-6
PILOT RATING (SP)	LOS	2.6	0.6	6/2	0.2	.17	-	PILOT
2 (3)								B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	No comment.
	ANY COMPLAINTS ABOUT - SENSITIVITY?	
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Final response not completely predictable.
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	Very little tendency to over-control.
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Okay
	ANY TENDENCY TO - PIO? OVERCONTROL?	
TURN COORDINATION: A PROBLEM?		No problem.
PERFORMANCE:	APPROACH -	Good
	LANDING, MOST - DIFFICULT?	No problem.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Good results.	

NOTE: P12A with gain changed.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P13	✓							2064-1
PILOT RATING (SP)	LOS	2.3	1.1	-/-	0.5	-	V	PILOT
3 (3)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	no problem
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no problem
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	very small overcontrolling in final response in flare
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	no
VELOCITY CONTROL: SATISFACTORY?		no problems
BANK ANGLE CONTROL:	SATISFACTORY? -	no problem
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		okay
PERFORMANCE:	APPROACH -	okay
	LANDING, MOST - DIFFICULT?	yes
EFFECTS OF WIND/TURBULENCE:		10 kts 20-30 degrees off runway but no effect
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Overcontrolled nose slightly in flare, pretty good airplane.	

NOTE. HOS - LAHOS Config. 4-7, force commands.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P13A	✓							2064-5
PILOT RATING (SP)	LOS	2.3	1.1	-/-	0.5	.05	V	PILOT
6 (5)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	little heavy in flare longitudinally
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE - ANY SPECIAL PILOT INPUTS? - ANY TENDENCY TOWARDS PIO? -	very good approach; in flare was overcontrolling back and forth in small PIO, fairly quick stayed in loop, not really divergent, had to be careful not to drive it
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? - ANY TENDENCY TO - PIO? OVERCONTROL?	okay
TURN COORDINATION: A PROBLEM?		okay
PERFORMANCE:	APPROACH -	no further comments
	LANDING, MOST - DIFFICULT?	yes
EFFECTS OF WIND/TURBULENCE:		not a factor
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Maybe a 7. No further comments.	

NOTE: P13 plus feel system delay.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P14								2064-3
PILOT RATING (SP)	LOS	2.1	1.0	-/-	0.5	.09	-	PILOT
5 (4)	✓							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	no comments
	ANY COMPLAINTS ABOUT - SENSITIVITY?	light longitudinally
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	a problem in the final flare; very nice airplane until one tried to quickly move attitude
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	high frequency, small amplitude oscillations
VELOCITY CONTROL: SATISFACTORY?		no problem
BANK ANGLE CONTROL:	SATISFACTORY? -	no problem
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE.	APPROACH -	piece of cake
	LANDING, MOST - DIFFICULT?	yes, in flare there was a high frequency bobble. Could back out, hold it and land 200 ft long
EFFECTS OF WIND/TURBULENCE:		not a factor
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Could be a 4. Comparison of P13 and P14: P13 - was over-controlling a bit, couldn't see a lag. No oscillations at all. P14 - bit more of overcontrol, quick oscillation was a definite difference in the flare but not in approach.	

NOTE: CS for P13, L_α fixed.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P15	✓							2064-2
PILOT RATING (SP)	LOS	1.1	0.7	2/-	1.5	-	-	PILOT
8 (9)								A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	little heavy longitudinal
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS <u>REQUIRED TO PERFORM TASK</u>:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	initial response very slow overcontrol final response
	ANY SPECIAL PILOT INPUTS? -	be very careful and smooth: avoid resorting to a bang-bang control
	ANY TENDENCY TOWARDS PIO? -	yes, there was a PIO but it was slow and not divergent
VELOCITY CONTROL: SATISFACTORY?		not satisfactory ± 2-3^o angle of attack variations
BANK ANGLE CONTROL:	SATISFACTORY? -	no problem
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	sluggish: overcontrolled it
	LANDING, MOST - DIFFICULT?	much more difficult, grossly overcontrolled attitude
EFFECTS OF WIND/TURBULENCE:		not a factor
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Aircraft lacked precision, could manage landing without losing it.	

NOTE: HOS - LAHOS Config. 1-4, force commands.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P15	✓							2070-3
PILOT RATING (SP)	LOS	1.1	0.7	2/-	1.5	-	-	PILOT
9 (10)								B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	No specific comments.
	ANY COMPLAINTS ABOUT - SENSITIVITY?	No
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Very poor
	ANY SPECIAL PILOT INPUTS? -	No
	ANY TENDENCY TOWARDS PIO? -	Continuous PIO even in turn.
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Yes
	ANY TENDENCY TO - PIO? OVERCONTROL?	No
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	Poor on approach turn as well as flare.
	LANDING, MOST - DIFFICULT?	Yes
EFFECTS OF WIND/TURBULENCE:		No effect
SUMMARY COMMENTS: ANY CHANGE IN RATING?		Very difficult to control in flare.

NOTE: HOS - LAHOS Config. 1-4, force commands.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P16								2072-2
PILOT RATING (SP)	LOS	0.8	0.6	-/-	1.4	.16	-	PILOT
8 (9)	✓							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY? ANY COMPLAINTS ABOUT - SENSITIVITY?	Longitudinal very heavy, particularly on ground and in the final part of the flare
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE - ANY SPECIAL PILOT INPUTS? - ANY TENDENCY TOWARDS PIO? -	Initial response very slow, final response also slow. Had to overdrive it. Last bit of flare and on groun there was a tendency towards P
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? - ANY TENDENCY TO - PIO? OVERCONTROL?	Yes No
TURN COORDINATION: A PROBLEM?		No problem.
PERFORMANCE:	APPROACH - LANDING, MOST - DIFFICULT?	No comments. Yes, heavy longitudinal forces.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Workload very high, could manhandle aircraft to control PIO.	

NOTE: ES for P15, L_a fixed.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P16A								2070-5
PILOT RATING (SP)	LOS	0.8	0.6	-/-	1.6	.14	-	PILOT
5 (7)	✓							B

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	All right.
	ANY COMPLAINTS ABOUT - SENSITIVITY?	No.
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	Slow PIO in approach.
	ANY SPECIAL PILOT INPUTS? -	Worked stick pretty hard longitudinally.
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		Okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Okay
	ANY TENDENCY TO - PIO? OVERCONTROL?	
TURN COORDINATION: A PROBLEM?		Okay
PERFORMANCE:	APPROACH -	Better on approach.
	LANDING, MOST - DIFFICULT?	Better in landing than approach.
EFFECTS OF WIND/TURBULENCE:		None
SUMMARY COMMENTS: ANY CHANGE IN RATING?		Tolerable in landing phase, 8 or 9 for approach.

NOTE: Modified ES for 15.

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P16A								2068-3
PILOT RATING (SP)	LOS	0.8	0.6	-/-	1.6	.14	-	PILOT
7 (8)	✓							C

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	very nice
	ANY COMPLAINTS ABOUT - SENSITIVITY?	apparent sluggishness longitudinally
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	not predictable
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	slight PIO
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	okay
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	okay
	LANDING, MOST - DIFFICULT?	yes, due to sluggishness in pitch
EFFECTS OF WIND/TURBULENCE:		effects magnified by sluggishness in response to counter simulated turbulence
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Forces higher than I'm used to in holding nose up during liftoff; tendency to bobble after touchdown. NOTE: Rating changed to a 7 after flight when rating scale definitions were reviewed.	

NOTE: Modified ES for P15

CONFIGURATION	HOS	ω	ζ	λ_D/λ_N	ϕ_{ss}/lb	DELAY	CARD	FLIGHT
P17								2064-4
PILOT RATING (SP)	LOS	1.9	0.8	0.7/-	1.2	-	-	PILOT
9 (10)	✓							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	longitudinal heavy to get adequate response in flare
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	pitch attitude very slow, final response unpredictable, in flare, nose came up, overcontrolled it, nose down...bounding down runway
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	large overcontrol tendencies
VELOCITY CONTROL: SATISFACTORY?		no problem
BANK ANGLE CONTROL:	SATISFACTORY? -	no problem
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	piece of cake
	LANDING, MOST - DIFFICULT?	yes, grossly overcontrol
EFFECTS OF WIND/TURBULENCE:		not a factor
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Difference between P15 and P17: both quite laggy, P17 lag was not obvious until in close, stick forces heavier than before - nose came up faster than before, causing much greater overcontrol problem than P15. (NOTE: pilot lost control in one landing, no record available.)	

NOTE: ES for P15, L_α free.

APPENDIX B

LATERAL PILOT COMMENTS

Brief summaries of the pertinent pilot comments for the lateral evaluation configurations are presented in this Appendix. The heading block information is consistent with the data summary table in Section VI-3. Note that the digit after the flight number represents the order in which the evaluation was performed on that flight.

CONFIGURATION	HOS-3	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
L1	✓	-	-	S	-		2083-3
PILOT RATING (SP)	LOS						PILOT
4 (4)							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	no comments
	ANY COMPLAINTS ABOUT - SENSITIVITY?	little too sensitive initially then sluggish for large turns
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	sensitive about neutral position but then had to overdrive, stopped right where you left it
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		not a factor
PERFORMANCE:	APPROACH -	initially quick, then slows down
	LANDING, MOST - DIFFICULT?	not much problem in flare
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Debating between a 4 and 5.	

NOTE: Advanced Fighter HOS-3 (45° Flap)

CONFIGURATION	HOS	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
L2							2083-4
PILOT RATING (SP)	LOS ✓	.5	.05	6	.07		PILOT
3 (4)							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	no comments
	ANY COMPLAINTS ABOUT - SENSITIVITY?	tiniest bit abrupt
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problem
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	yes, response a bit abrupt; got some jerkiness but not much
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no
PERFORMANCE:	APPROACH -	had to overdrive bank some but it stops where I wanted it
	LANDING, MOST - DIFFICULT?	no
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Similar to 2083-3 (L1). Forces a little heavier here. Debated between 3 and 4..	

NOTE: ES for L1

CONFIGURATION	HOS-4	τ_R	τ_{LAG}	ϕ_{SS}/lb	DELAY		FLIGHT
L3	✓						2080-2
PILOT RATING (SP)	LOS	-	-	5	-		PILOT
4 (S)							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	strange force feel in roll during sidesteps
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problem
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	felt strange; initial response slow, but when input removed aircraft stopped right there
	ANY TENDENCY TO PIO? OVERCONTROL? -	occasional very small oscillation
TURN COORDINATION: A PROBLEM?		
PERFORMANCE:	APPROACH -	sidestep showed up annoying feel characteristics and occasionally little oscillation
	LANDING, MOST DIFFICULT? -	no, would like to see it in turbulence
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Could do the job but wasn't pleasant because of roll response.	

NOTE: Advanced Fighter HOS-4 (30° Flap)

CONFIGURATION	HOS	τ_R	τ_{LAG}	F_{SS}/lb	DELAY		FLIGHT
L4							2080-5
PILOT RATING (SP)	LOS	0.5	0.05	10	.05		PILOT
4 (4)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	light in roll
	ANY COMPLAINTS ABOUT - SENSITIVITY?	little too sensitive in roll
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	okay
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	Little too sensitive, abrupt initially; final response was precise
	ANY TENDENCY TO PIO? OVERCONTROL? -	some tendency for small overcontrol due to lateral sensitivity
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	okay
	LANDING, MOST DIFFICULT? -	no special problems related to flare
EFFECTS OF WIND/TURBULENCE:		very calm
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Changed to rating 4 after comments.	

NOTE: ES for L3

CONFIGURATION	HOS	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
L4A		0.5	0.05	7	.05		2080-3
PILOT RATING (SP)	LOS						PILOT
3 (3)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	lateral forces little lighter than desired
	ANY COMPLAINTS ABOUT - SENSITIVITY?	
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problem
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	no problem except sidestep; a little quicker laterally than I would have liked
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	had to take it easy in side-step because of high lateral sensitivity
	LANDING, MOST - DIFFICULT?	no
EFFECTS OF WIND/TURBULENCE:		none, unfortunately
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Comparison with L3: not alike at all, this one was light and responsive but first one was abrupt, heavy and required overdriving.	

NOTE: L4 with gain changed.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
LS							2077-1
PILOT RATING (SP)	LOS	0.6	0.05	4	-		PILOT
2 (2)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	no problems, little sluggish perhaps
	ANY TENDENCY TO PIO? OVERCONTROL? -	no
TURN COORDINATION: A PROBLEM?		no problems
PERFORMANCE:	APPROACH -	tended to overdrive more at downwind and base position than in flare
	LANDING, MOST DIFFICULT? -	no problem, easier than approach
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	could fly it all day	

NOTE: Short time constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	F_{SS}/lb	DELAY		FLIGHT
LS							2084-1
PILOT RATING (SP)	LOS						PILOT
2 (2)	✓	0.6	0.05	5	-		C

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	forces light, roll displacements a bit large for personal liking
	ANY COMPLAINTS ABOUT - SENSITIVITY?	okay
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	very nice
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		satisfactory
BANK ANGLE CONTROL:	SATISFACTORY? -	very predictable, even on large sidestep
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no problems; no rudder required
PERFORMANCE:	APPROACH -	lower workload
	LANDING, MOST - DIFFICULT?	yes, but no problem
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Good aircraft.	

NOTE: Short Time Constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
LS							2081-2
PILOT RATING (SP)	LOS	0.5	0.05	4	-		PILOT
2 (1)	✓						D

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	pretty good
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no problems
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problem
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	good
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		okay, some adverse yaw on sidesteps
PERFORMANCE:	APPROACH -	no difficulty
	LANDING, MOST - DIFFICULT?	no problem
EFFECTS OF WIND/TURBULENCE:		none except for side wind after touchdown from a large helicopter
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Not a lot of difference between this and previous configuration (L16A).	

NOTE: Short Time Constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
L5A							2076-1
PILOT RATING (SP)	LOS	0.6	-	3	-		PILOT
3 (3)	✓						D

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	satisfactory
	ANY COMPLAINTS ABOUT - SENSITIVITY?	not overly sensitive
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	little slop around neutral but not bothersome
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	no
VELOCITY CONTROL: SATISFACTORY?		satisfactory
BANK ANGLE CONTROL:	SATISFACTORY? -	satisfactory
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		good
PERFORMANCE:	APPROACH -	simple
	LANDING, MOST - DIFFICULT?	easy, but must learn to compensate for floating tendency of T-33
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	satisfactory	

NOTE: L5 without Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	F_{SS}/lb	DELAY		FLIGHT
L6							2073-4
PILOT RATING (SP)	LOS	0.4	0.1	5	-		PILOT
2 (2)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	no problem
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	super, did what I wanted even before I was aware I was telling it to do that
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		okay
PERFORMANCE:	APPROACH -	good
	LANDING, MOST - DIFFICULT?	good
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Rating 1 laterally, 2 overall, everything was good.	

NOTE: Short time constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	F_{SS}/lb	DELAY		FLIGHT
L7							2079-5
PILOT RATING (SP)	LOS ✓	0.4	0.2	5	-		PILOT
3 (2)							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	no comments
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	had to overdrive aircraft a little to get desired response, but seemed to stop crisply
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no comments
PERFORMANCE:	APPROACH -	okay
	LANDING, MOST - DIFFICULT?	no problems
EFFECTS OF WIND/TURBULENCE:		not a factor
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Debated between 2 and 3, selected 3.	

NOTE: Short time constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
L7A							2083-7
PILOT RATING (SP)	LOS	0.4	0.2	5	.09		PILOT
4 (3)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	fairly heavy forces laterally
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no comments
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	no, overdriving required to get what you want
	ANY TENDENCY TO - PIO? OVERCONTROL?	no, stops where you want it
TURN COORDINATION: A PROBLEM?		not a factor
PERFORMANCE:	APPROACH -	okay, but must work at sidesteps
	LANDING, MOST - DIFFICULT?	same comments
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Must "push" airplane to get desired performance.	

NOTE: L7 with time delay.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ϕ_{SS}/lb	DELAY		FLIGHT
L8							2078-1
PILOT RATING (SP)	LOS ✓	0.6	0.5	5	-		PILOT
5 (5)							A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	needed "bang-bang" control inputs in large sidestep, little sluggish oscillatory
	ANY TENDENCY TO - PIO? OVERCONTROL?	yes, slight PIO tendency - very slow oscillations
TURN COORDINATION: A PROBLEM?		not a factor
PERFORMANCE:	APPROACH -	no problem, except sidestep
	LANDING, MOST - DIFFICULT?	gust caused some problem, led to roll oscillations
EFFECTS OF WIND/TURBULENCE:		small crosswind, not really a major problem
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Had to be flown smoothly in roll. Sidestep was the problem in roll. Overcontrolled, slow lacks predictability.	

NOTE: Short time constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ϕ_{SS}/lb	DELAY		FLIGHT
L8A		0.4	1.0	7	-		2079-4
PILOT RATING (SP)	LOS						PILOT
6 (5)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY? ANY COMPLAINTS ABOUT - SENSITIVITY?	
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE ANY SPECIAL PILOT INPUTS? - ANY TENDENCY TOWARDS PIO? -	- no comments
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? - ANY TENDENCY TO - PIO? OVERCONTROL?	turning final get an overshoot in bank then 3 to 4 oscillations sidestep caused a little overcontrol past desired bank angle. Oscillations slow enough that there was no danger of losing it in a PIO.
TURN COORDINATION: A PROBLEM?		okay
PERFORMANCE:	APPROACH - LANDING, MOST - DIFFICULT?	sidesteps were the problem flare no problem in calm winds
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	suspect more problems would show up in the flare with a gusty crosswind	

NOTE: Short time constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ϕ_{SS}/lb	DELAY		FLIGHT
L8B							2086-6
PILOT RATING (SP)	LOS	0.4	1.4	5	-		PILOT
9 (8)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	
PITCH ATTITUDE RESPONSE TO INPUTS <u>REQUIRED TO</u> <u>PERFORM TASK</u>:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	slow to respond then over-control on final turn and sidestep
	ANY TENDENCY TO - PIO? OVERCONTROL?	yes, easy to overcontrol
TURN COORDINATION: A PROBLEM?		not a factor
PERFORMANCE:	APPROACH -	had to "back out" of task during sidestep
	LANDING, MOST - DIFFICULT?	yes. So much attention required on lateral that pitch was messed up. Landed long.
EFFECTS OF WIND/TURBULENCE:		
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Concerned about hitting tip tanks, dangerous aircraft in close in roll.	

NOTE: Short time constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
L8B							2081-5
PILOT RATING (SP)	LOS	0.4	1.4	5	-		PILOT
5 (6)	✓						D

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	lateral forces weren't good, forces high, large displacements
	ANY COMPLAINTS ABOUT - SENSITIVITY?	less than what I'd like in roll
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	adequate, lag noticed in initial response
	ANY TENDENCY TO - PIO? OVERCONTROL?	slight tendency to overcontrol in bank and slight tendency to PIO when trying to take bank out
TURN COORDINATION: A PROBLEM?		considerable adverse yaw, not comfortable
PERFORMANCE:	APPROACH -	not a problem
	LANDING, MOST - DIFFICULT?	more problem, especially with sidestep
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	System can perform the task but I didn't like it.	

NOTE: Short time constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
L9							2079-3
PILOT RATING (SP)	LOS	0.4	0.05	5	.09		PILOT
2 (2)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	no problems
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no comments
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		good
BANK ANGLE CONTROL:	SATISFACTORY? -	crisp, sure good predictability; little lag noticed in initial response
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	easy
	LANDING, MOST - DIFFICULT?	no problem
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Debating 2 to 3 rating, settled on 2.	

NOTE: Short time constant - Time delay.

CONFIGURATION	HOS	τ_R	τ_{LAG}	φ_{SS}/lb	DELAY		FLIGHT
L10							2077-4
PILOT RATING (SP)	LOS	0.4	0.05	5	.14		PILOT
5 (4)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	too sensitive in roll
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problem
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	abrupt, jerky response, too sensitive but predictable, some delay noticed
	ANY TENDENCY TO - PIO? OVERCONTROL?	yes, PIO in gusty conditions
TURN COORDINATION: A PROBLEM?		okay
PERFORMANCE:	APPROACH -	no problem but annoying to have abruptness in roll axis
	LANDING, MOST - DIFFICULT?	yes, gustiness caused major problems
EFFECTS OF WIND/TURBULENCE:		caused overcontrol, tendency toward PIO; probably be worse in more gusty conditions
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Very gust responsive in roll. Would be worse in strong turbulence.	

NOTE: L10 without filter.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
L10A							2076-3
PILOT RATING (SP)	LOS	0.4	-	3	.14		PILOT
3.5 (4)	✓						D

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	satisfactory
	ANY COMPLAINTS ABOUT - SENSITIVITY?	satisfactory
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	nothing changed
	ANY SPECIAL PILOT INPUTS? -	no
	ANY TENDENCY TOWARDS PIO? -	little pitch oscillation on second landing
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	okay
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		small adverse yaw but no problem
PERFORMANCE:	APPROACH -	no problems
	LANDING, MOST - DIFFICULT?	no problems
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	satisfactory	

NOTE: Short time constant - Time delay.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ϕ_{SS}/lb	DELAY		FLIGHT
L11							2078-6
PILOT RATING (SP)	LOS	0.4	0.05	4	.20		PILOT
3 (4)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	satisfactory
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		
BANK ANGLE CONTROL:	SATISFACTORY? -	initial response little slow; slight tendency to overcontrol final response
	ANY TENDENCY TO - PIO? OVERCONTROL?	no PIO
TURN COORDINATION: A PROBLEM?		not a factor
PERFORMANCE:	APPROACH -	noticed a little requirement to use opposite control to stop roll rate
	LANDING, MOST - DIFFICULT?	sidesteps were the problem area
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Might have been different in a gusty crosswind.	

NOTE: Short time constant - Time delay.

CONFIGURATION	HOS	τ_R	τ_{LAG}	F_{SS}/lb	DELAY		FLIGHT
L11A, L11, L11B							2084-3
PILOT RATING (SP)	LOS	0.4	0.05	5,4,3	.20		PILOT
6,5,4 (5)	✓						C

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	no comments
	ANY COMPLAINTS ABOUT - SENSITIVITY?	a little too sensitive initially (A)
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		satisfactory
BANK ANGLE CONTROL:	SATISFACTORY? -	no, too sensitive (A); little oversensitive in close (L11); little on sluggish side (B).
	ANY TENDENCY TO - PIO? OVERCONTROL?	no, but needed high frequency stick oscillation to control (A)
TURN COORDINATION: A PROBLEM?		not a factor
PERFORMANCE:	APPROACH -	did not reveal deficiencies, okay
	LANDING, MOST - DIFFICULT?	yes
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	No change in ratings.	

NOTE: Approach #1, L11A; L11 with gain change.
Approach #2, L11; Short time constant - Time delay.
Approach #3, L11B; L11 with gain change.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
L11C							2083-6
PILOT RATING (SP)	LOS	0.4	0.05	6	.30		PILOT
9 (9)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	
	ANY COMPLAINTS ABOUT - SENSITIVITY?	a little bit slow initially, then abrupt start
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	no, slow then abrupt
	ANY TENDENCY TO PIO? OVERCONTROL? -	little PIO when stopping roll once I got out of loop, stopped right there
TURN COORDINATION: A PROBLEM?		not a factor
PERFORMANCE:	APPROACH -	sidesteps a problem; easy to PIO
	LANDING, MOST DIFFICULT? -	lot of effort required to avoid lateral PIO
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Debate between 8 and 9. Quick little roll PIO in sidestep maneuvers when stopping.	

NOTE: Short time constant - Time delay.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
L11C							2081-4
PILOT RATING (SP)	LOS	0.4	0.05	5	.30		PILOT
6 (8)	✓						D

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	not bad
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no comments
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problem
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	due to lag to roll response there was a tendency to over-control
	ANY TENDENCY TO PIO? OVERCONTROL? -	yes, but mainly in making small inputs in flare
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	no problem; tendency to over-control, less for large corrections
	LANDING, MOST - DIFFICULT?	yes, PIO tendency greatest just before touchdown
EFFECTS OF WIND/TURBULENCE:		calm but could probably go to a 9 or 10 if in gusty conditions
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Rating could be a little lenient but will stay with a 6.	

NOTE: Short time constant - Time delay.

CONFIGURATION	HOS	τ_R	τ_{LAG}	F_{SS}/lb	DELAY		FLIGHT
L11D							2078-2
PILOT RATING (SP)	LOS	0.5	0.5	5	.15		PILOT
10 (10)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	no comments
	ANY COMPLAINTS ABOUT - SENSITIVITY?	fairly sensitive
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no comments
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	very poor even with the lowest time delay
	ANY TENDENCY TO - PIO? OVERCONTROL?	very definitely, dangerous aircraft
TURN COORDINATION: A PROBLEM?		not a factor
PERFORMANCE:	APPROACH -	no problems
	LANDING, MOST - DIFFICULT?	wind picked up right wing, over-controlled correction. Safety Pilot took control at 2 ft. in air. Could have lost airplane if we hadn't been quick.
EFFECTS OF WIND/TURBULENCE:		disturbances lead to PIO.
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Debatable whether I was going to be able to land it all the way. (with more than 150 MS delay, it's a disaster)	

NOTE: Short time constant - Lag plus time delay.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
L12							2083-1
PILOT RATING (SP)	LOS	1.2	0.05	6	-		PILOT
5 (4)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	heavy lateral forces
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no comments
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	slow getting to desired bank angle, had to anticipate roll out. Had to ease off on corrections.
	ANY TENDENCY TO - PIO? OVERCONTROL?	no real oscillations, very slow overcontrol.
TURN COORDINATION: A PROBLEM?		no comments
PERFORMANCE:	APPROACH -	no problem except for sidestep corrections
	LANDING, MOST - DIFFICULT?	no real problem in flare
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	No comments.	

NOTE: Long time constant - lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ϕ_{SS}/lb	DELAY		FLIGHT
L12							2077-2
PILOT RATING (SP)	LOS	1.0	0.05	6	-		PILOT
4 (4)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	noticed lag only during sidestep task, normal landing didn't show
	ANY TENDENCY TO PIO? OVERCONTROL? -	tendency to get too much roll and overcontrol
TURN COORDINATION: A PROBLEM?		not perfect but not a factor
PERFORMANCE:	APPROACH -	some problem with bank angle precision on final turn
	LANDING, MOST DIFFICULT? -	yes, with aggressive lateral tasks
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Not much difficulty during normal landing, but aggressive sideslip showed lag and overcontrol tendency.	

NOTE: Long time constant - lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	φ_{SS}/lb	DELAY		FLIGHT
L12A							2076-2
PILOT RATING (SP)	LOS	.9	-	5	-		PILOT
3.5 (3)	✓						D

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	forces little higher laterally
	ANY COMPLAINTS ABOUT - SENSITIVITY?	might prefer a little more in roll
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problem
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		better with practice
BANK ANGLE CONTROL:	SATISFACTORY? -	okay
	ANY TENDENCY TO PIO? OVERCONTROL? -	none
TURN COORDINATION: A PROBLEM?		nothing too distracting, little adverse yaw
PERFORMANCE:	APPROACH -	about same, no problem
	LANDING, MOST DIFFICULT? -	no problem
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	no problems (Safety Pilot comment: very smooth, predictive pilot)	

NOTE: L12 without lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
L13							2079-1
PILOT RATING (SP)	LOS	1.2	0.1	6	-		PILOT
4 (4)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	on turn to final, little slow into bank, overcontrolled
	ANY TENDENCY TO PIO? OVERCONTROL? -	oscillated about final bank angle; tended to overturn in sidesteps
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	opposite control to stop roll rate required in sidestep
	LANDING, MOST DIFFICULT? -	no problem in flare in absence of gusts
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Sluggish initial response in sidesteps, tended to overcontrol.	

NOTE: Long time constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ϕ_{SS}/lb	DELAY		FLIGHT
L14		1.2	0.2	6	-		2080-1
PILOT RATING (SP)	LOS						PILOT
5 (5)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	no problem
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problem
	ANY SPECIAL PILOT INPUTS? =	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	little sluggish on initial response, had to overdrive to get desired response, would overshoot then oscillate
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	didn't want to do sidestep aggressively because of over-control tendency
	LANDING, MOST - DIFFICULT?	no
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Required lot of lead to fly without overshoot. Could be a 6 but stay with 5 rating.	

NOTE: Long time constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ϕ_{SS}/lb	DELAY		FLIGHT
L14							2077-3
PILOT RATING (SP)	LOS	.9	0.2	6	-		PILOT
7 (6)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problem
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	noticed lag on rollout more than roll in, not acceptable
	ANY TENDENCY TO PIO? OVERCONTROL? -	could not bring myself to put in large corrections around pattern and during sidesteps
TURN COORDINATION: A PROBLEM?		not a factor
PERFORMANCE:	APPROACH -	piece of cake
	LANDING, MOST - DIFFICULT?	sidestep was difficult for roll task and there was more pitch oscillation than desired
EFFECTS OF WIND/TURBULENCE:		gusty crosswind present, a problem in combination with large sidestep
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Almost initiated wave-off during large sidestep, aggressive roll control not possible.	

NOTE: Long time constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	φ_{SS}/lb	DELAY		FLIGHT
L14							2076-4
PILOT RATING (SP)	LOS	.9	0.2	5	-		PILOT
3 (3)	✓						D

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	satisfactory
	ANY COMPLAINTS ABOUT - SENSITIVITY?	reasonably sensitive in roll
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		satisfactory
BANK ANGLE CONTROL:	SATISFACTORY? -	yes, good
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		little adverse yaw but no problem
PERFORMANCE:	APPROACH -	no problems
	LANDING, MOST - DIFFICULT?	about the same
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	satisfactory	

NOTE: Long time constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
L14A							2077-5
PILOT RATING (SP)	LOS	.9	.5	7	-		PILOT
8 (8)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	no, slow in initial response then to stop roll must control in opposite direction
	ANY TENDENCY TO PIO? OVERCONTROL? -	yes, slow oscillation in sidesteps small opposite inputs required
TURN COORDINATION: A PROBLEM?		not a factor
PERFORMANCE:	APPROACH -	quick sidestep or gustiness easily excited, lateral oscillations
	LANDING, MOST - DIFFICULT?	yes, oscillatory for quick inputs in gusts near the ground
EFFECTS OF WIND/TURBULENCE:		moderate gusts lead to roll oscillations
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Rating 7 for smooth air, rating 8 for gusty air due to lateral oscillations.	

NOTE: Long time constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ϕ_{SS}/lb	DELAY		FLIGHT
L14A							2081-3
PILOT RATING (SP)	LOS	.9	0.5	6	-		PILOT
3 (4)	✓						D

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	pretty good
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no problems
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problem
	ANY SPECIAL PILOT INPUTS? -	-
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	good
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		adverse yaw apparent, but not a problem
PERFORMANCE:	APPROACH -	no difficulty
	LANDING, MOST - DIFFICULT?	no problem
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Appeared very similar to two previous configurations. Same comments 2081-2 (L5).	

NOTE: Long time constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ϕ_{SS}/lb	DELAY		FLIGHT
L14A							2076-5
PILOT RATING (SP)	LOS	.9	0.5	5	-		PILOT
4 (5)	✓						D

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	seemed excessive in roll
	ANY COMPLAINTS ABOUT - SENSITIVITY?	little low in roll
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	okay
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	yes, except gust caused problem
	ANY TENDENCY TO - PIO? OVERCONTROL?	no, just too slow to correct for gust
TURN COORDINATION: A PROBLEM?		no problem
PERFORMANCE:	APPROACH -	no problem
	LANDING, MOST - DIFFICULT?	same as approach
EFFECTS OF WIND/TURBULENCE:		one gust, caused problem laterally
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Gust upset on final on one approach. Lateral response slower than I wanted. Offset no problem. Suspect that control in turbulence would be a major problem.	

NOTE: Long time constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ϕ_{SS}/lb	DELAY		FLIGHT
L14B							2085-2
PILOT RATING (SP)	LOS	1.2	1.0	6	-		PILOT
10 (10)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	no comments
	ANY COMPLAINTS ABOUT - SENSITIVITY?	slow in initial response
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	no, slow to respond; went to 50 degree bank when 30 degree wanted then overcontrolled other way
	ANY TENDENCY TO - PIO? OVERCONTROL?	yes, slow PIO in sidestep
TURN COORDINATION: A PROBLEM?		not a factor
PERFORMANCE:	APPROACH -	bank control required a lot of pilot attention to avoid lateral PIO in sidesteps
	LANDING, MOST - DIFFICULT?	could get it down but had to be very careful
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Did not want to do a large sidestep, afraid to do it. (Rating of 9 for small sidestep task.)	

NOTE: Long time constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ϕ_{SS}/lb	DELAY		FLIGHT
L14B							2084-2
PILOT RATING (SP)	LOS	1.0	1.0	6	-		PILOT
8 (9)	✓						C

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	large roll forces and displacements
	ANY COMPLAINTS ABOUT - SENSITIVITY?	
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problem
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		no problem
BANK ANGLE CONTROL:	SATISFACTORY? -	had to overdrive laterally both roll in and out
	ANY TENDENCY TO PIO? OVERCONTROL? -	PIO every approach in close
TURN COORDINATION: A PROBLEM?		not a factor
PERFORMANCE:	APPROACH -	sluggish response, could be seen on approach
	LANDING, MOST DIFFICULT? -	yes, PIO every occasion, had to get off controls
EFFECTS OF WIND/TURBULENCE:		none, but would have caused big problems
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Had to use opposite control to stop roll attitudes. A well earned rating of 8.	

NOTE: Long time constant - Lag.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ϕ_{SS}/lb	DELAY		FLIGHT
L15							2083-5
PILOT RATING (SP)	LOS	.9	0.05	9	.09		PILOT
4 (3)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	heavy laterally
	ANY COMPLAINTS ABOUT - SENSITIVITY?	would like something a little more responsive
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	overdrove it a little; it was slow enough though that I could do it if I wanted a better response
	ANY TENDENCY TO - PIO? OVERCONTROL?	
TURN COORDINATION: A PROBLEM?		not a factor.
PERFORMANCE:	APPROACH -	no real problems except need to overdrive response
	LANDING, MOST - DIFFICULT?	no problem at all
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Wanted a more responsive roll control.	

NOTE: Long time constant - Time delay.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
L15							2078-3
PILOT RATING (SP)	LOS	.9	0.05	6	.09		PILOT
5 (5)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	not too bad in pattern, but in sidestep initial response delayed tended to overcontrol final respo:
	ANY TENDENCY TO - PIO? OVERCONTROL?	sidestep forced "bang-bang" contr overcontrolled bank angle
TURN COORDINATION: A PROBLEM?		okay
PERFORMANCE:	APPROACH -	piece of cake
	LANDING, MOST - DIFFICULT?	didn't see roll problem in flare, only in sidestep
EFFECTS OF WIND/TURBULENCE:		not a factor
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Debated between a 4 and 5 - selected 5.	

NOTE: Long time constant - Time delay.

CONFIGURATION	HOS	τ_R	τ_{LAG}	φ_{SS}/lb	DELAY		FLIGHT
L16							2079-2
PILOT RATING (SP)	LOS	1.0	0.05	6	.14		PILOT
3 (5)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	okay, slightly heavy in roll
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no comments
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	on turn to final aggressive banking would cause an overshoot but not oscillate
	ANY TENDENCY TO - PIO? OVERCONTROL?	some overcontrol
TURN COORDINATION: A PROBLEM?		
PERFORMANCE:	APPROACH -	sidestep caused overshoot but no oscillations
	LANDING, MOST - DIFFICULT?	not many problems
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Safety Pilot comments: some wing wobble noted in final stages of the landing.	

NOTE: Long time constant - Time delay.

CONFIGURATION	HOS	τ_R	τ_{LAG}	F_{SS}/lb	DELAY		FLIGHT
L16							2078-5
PILOT RATING (SP)	LOS	.9	0.05	6	.14		PILOT
4 (4)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	okay
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	quick to respond but not predictable, overcontrolled
	ANY TENDENCY TO - PIO? OVERCONTROL?	overcontrol in sidestep, no PIO tendency, needed opposite input to stop
TURN COORDINATION: A PROBLEM?		okay
PERFORMANCE:	APPROACH -	no problems
	LANDING, MOST - DIFFICULT?	sidestep was the problem area
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	Not great but problems are minor.	

NOTE: Long time constant - Time delay.

CONFIGURATION	HOS	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
L16A							2080-4
PILOT RATING (SP)	LOS	.9	0.05	6	.20		PILOT
8 (8)	✓						A

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	no comments
	ANY COMPLAINTS ABOUT - SENSITIVITY?	no comments
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	
	ANY TENDENCY TO - PIO? OVERCONTROL?	initial delay then aircraft would respond quickly and overshoot laterally; a little tendency to PIO but not divergent
TURN COORDINATION: A PROBLEM?		no comments
PERFORMANCE:	APPROACH -	had to "backoff" control during sidestep. Controllability was in question in severe lateral tasks
	LANDING, MOST - DIFFICULT?	small oscillations in the flare, gusty crosswind would be a problem
EFFECTS OF WIND/TURBULENCE:		none
SUMMARY COMMENTS: ANY CHANGE IN RATING?	No further comments.	

NOTE: Long time constant - Time delay.

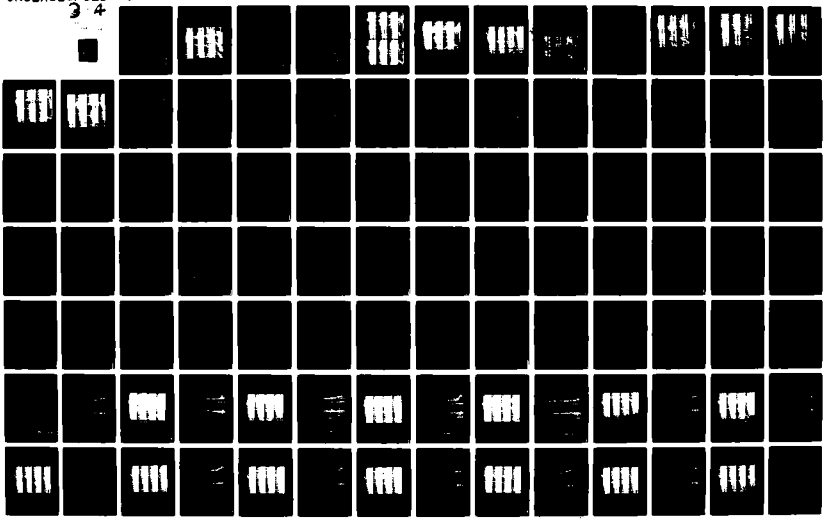
CONFIGURATION	HOS	τ_R	τ_{LAG}	ρ_{SS}/lb	DELAY		FLIGHT
L16A							2081-1
PILOT RATING (SP)	LOS	1.2	0.05	6	.20		PILOT
3 (4)	✓						D

FEEL CHARACTERISTICS:	FORCES, DISPLACEMENTS - SATISFACTORY?	satisfactory
	ANY COMPLAINTS ABOUT - SENSITIVITY?	okay
PITCH ATTITUDE RESPONSE TO INPUTS REQUIRED TO PERFORM TASK:	INITIAL RESPONSE, PREDICTABILITY OF FINAL RESPONSE -	no problems
	ANY SPECIAL PILOT INPUTS? -	
	ANY TENDENCY TOWARDS PIO? -	
VELOCITY CONTROL: SATISFACTORY?		okay
BANK ANGLE CONTROL:	SATISFACTORY? -	good
	ANY TENDENCY TO - PIO? OVERCONTROL?	no
TURN COORDINATION: A PROBLEM?		some adverse yaw on sidesteps, not a problem
PERFORMANCE:	APPROACH -	good
	LANDING, MOST - DIFFICULT?	good
EFFECTS OF WIND/TURBULENCE:		none, calm conditions
SUMMARY COMMENTS: ANY CHANGE IN RATING?	System was adequate for these tasks.	

NOTE: Long time constant - Time delay.

AD-A119 704 CALSPAN CORP BUFFALO NY FLIGHT RESEARCH DEPT F/G 1/2
EQUIVALENT SYSTEM VERIFICATION AND EVALUATION OF AUGMENTATION E--ETC(U)
SEP 81 R E SMITH, J HODGKINSON, R C SNYDER F33615-78-C-3602
UNCLASSIFIED CALSPAN-6241-F-3-VOL-2 AFWAL-TR-81-3116-VOL-2 NL

3 4



APPENDIX C

COMPARISON OF RATINGS AND COMMENTS FOR

EQUIVALENT SYSTEMS

This Appendix compares, in detail, the pilot rating and command data for high and low order systems designated as equivalents.

Longitudinal Equivalents:

High Order System No. 1 (P1). Equivalents; P2, P2A (L_α Fixed); P3, P3A (L_α Free)

The high order configuration P1 was flown by 3 evaluation pilots and was awarded ratings of 2,2, and 3 for a mean of 2-1/3. All three pilots noted negligible deficiencies. Pilot A stated "teeniest bit of overcontrol on nose but predictable." There were no comments on control forces, displacements, and sensitivity. Pilot B had even less to say, just stating in summary "negligible deficiencies." Pilot C had minor comments, stating that the control forces and displacements were "satisfactory," sensitivity was "no problem,' and the initial response was "very predictable." In summary, he said "rating a 2 to 3."

The low order configuration P2 (L_α fixed match) was evaluated once by Pilot A. He gave this configuration a rating of 2, essentially the same as the high order P1. Slight differences in comments can be ascribed to the lower steady state gain than P1 (0.6 deg/sec/lb versus 0.8 deg/sec/lb for P1). Comments were: "longitudinal sensitivity low" and "heavy longitudinal forces in last bit of flare and touchdown." But he also commented "initial response okay, predictable final reponse" and "little bit of overcontrol at touchdown," so the basic dynamics were indistinguishable from P1.

Configuration P2A was evaluated by Pilot C. His comments included: "too much sensitivity, had to keep my inputs small" and, in summary, "could do job but too sensitive in pitch." P2A has a higher gain and slightly higher frequency than P2, which explains these comments and his rating of 4. However, Pilot C also found the lateral dynamics sensitive, so his results, taken with Pilot A's, indicate reasonable equivalence.

Two different gains were implemented on the L_α free equivalents. Configuration P3 had a lower gain than P1 (0.6 versus 0.8) and this makes it comparable to P2. Pilot A evaluated the configuration and gave it a rating of 3. His comments were "slightly heavy longitudinal in flare," "little lag, tended (to) slight overcontrol," and, on special pilot inputs "little tendency to put input in then wait." The comment on overcontrol tendency also appeared for the HOS, P1. The remaining comments are all qualified with 'small' and 'little' and the rating is virtually the same as P1, so reasonable equivalence is demonstrated.

Pilot B evaluated Configuration P3A with a gain of .9 deg/sec/lb awarded it a rating of 3. The comments were "tendency to overcontrol in flare" and the sensitivity was "not too bad." The response was not therefore noticeably different from the high order P1 dynamics.

These configurations were not selected for Fast Fourier analysis of the flight time history data. An early decision was made to study equivalent systems which received generally poor pilot ratings, which did not include these systems. However, for graphical comparison with pilot comments the analytical solutions of the frequency characteristics are shown in Figure C-1.

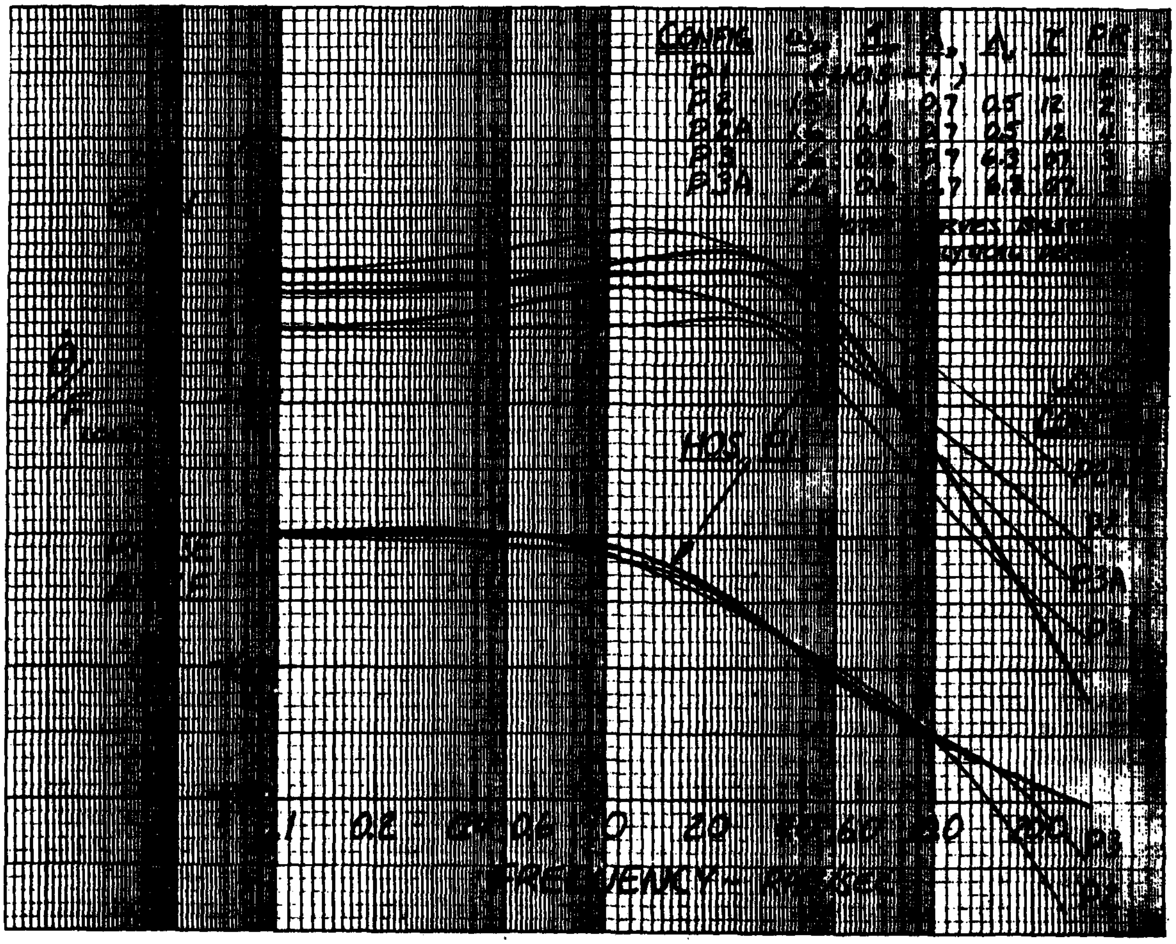


Figure C-1. Equivalent Low Order Systems, Level 1

The equivalent systems for P1 possessed mismatches of 136 for P2 and 348 for P3 and 34 for P3A. There is no apparent correlation between the comments and the numerical mismatch values. In summary, reasonable equivalence was therefore demonstrated by these configurations.

High Order System #2 (P4, P4A). Equivalents; P5, P5A, P5B, P5C (L_α Fixed); P6 (L_α Free).

The high order configuration P4 was evaluated 3 times; once by Pilot A and twice by Pilot B. Pilot A awarded it a rating of 3. His summary comments were "nice until flare then noticed lag, slight overcontrol." Pilot B's ratings were 4 and 3. Both times he commented on the work involved - "worked hard in flare, landed long first time or two." and "little difficult to establish initial pitch attitude, worked fairly hard." Sensitivity was also noticed - "tendency to overcontrol due to sensitivity" and "saw a little 'hunting' in pitch."

The gain variation of this system, P4A, was an attempt to lower the sensitivity and re-evaluate the dynamics. However, this configuration was landed only once at the end of a flight, so the rating of 2 is questionable.

The equivalent systems P5, P5A, P5B, P5C explored variations of numerator term L_α and gain. In the first evaluation, configuration P5 was flown by Pilot A and had a gain value of 1.1 deg/sec/lb, which is less than the 1.3 value for the high order system P4. The rating was 6, or 3 Cooper-Harper points higher (i.e., worse) than his rating for P4. His comments were "slightly heavy" forces, "overcontrolled final response, quick response," and "nice airplane until quick inputs caused PIO's." Clearly, his comments indicate less than desirable characteristics. The flare and touchdown were the most troublesome -"small oscillations in flare and touchdown, small amplitude PIO," which is what he commented on for P4. Also he stated "good if satisfied with a landing 500' long," very similar to Pilot B's statement on P4. Except for the comments on PIO's, the problems are similar to the high order response. It is questionable though that the gain change is responsible for the difference in ratings.

Pilot B evaluated the low order system P5, with a slightly lowered command gain of 1.0 deg/sec/lb. The rating was 6. The comments suggest problems with gain - "longitudinal was too sensitive and, when asked if any special pilot inputs were needed, he said "yes, careful attention required, had to lower gain." The pilot found no tendency to PIO, "but worked stick hard to avoid," which is an apparent contradiction. The initial and final response appeared as "not getting what I wanted or when." In summary, the aircraft "borders on a 7." Assuming his piloting technique suppressed the PIO and overshoot tendencies found by Pilot A for P5, Pilot B approximately echoes Pilot A's evaluation.

The low order system was also flown with gain approximately half the high order system value (0.7 versus 1.3 for P4), and L_α values of .55 and .8 configurations P5B, and P5C were evaluated by Pilots A and B and given ratings of 2 and 3. The control forces, displacements, and sensitivities were "okay," the initial response had "slight hesitation and tendency to overcontrol," and "had to put input in and wait." Finally "could overcontrol nose in flare

- minor problem." These comments agree closely with the evaluation of P4, and the ratings are identical. It is noticeable that the shift in steady state gain between P5 and P5B and the high order P4 brings the P5B high frequency gains (greater than 10 rad/sec) in closer alignment. This comparison is illustrated in Figure C-2.

The L_α free equivalent of P4, configuration P6, was flown with only one gain, and was evaluated once each by Pilots A and B. Pilot A gave it a rating of 4. His comments were very similar to those on P4 - "little bit of lag then bit of overcontrol" and "wouldn't get PIO if you let it land 500 ft long." Pilot B's comments centered on the sensitivity - "sensitive nose, took a very light hand on stick" and the response was "predictable but sensitive," but the rating was a 4. The gain on these evaluations was not significantly different from the high order system (P6 like P5B shows close alignment with P4 at the high frequency gains.)

For this group of configurations, the test data analyses suggest that a high frequency gain match is necessary.

<u>High Order System #3 (P7)</u>. Equivalents; P8 (L_α Fixed), P9 (L_α Free)

This high order system duplicated a configuration run on the previous LAHOS (Reference 4) experiment. The dynamics were designated 4-3 in LAHOS and P7 in this system evaluation. The LAHOS experiment, however, had a series feel system while the ESP used a parallel feel system. The second order lag feel system of the LAHOS is equivalent to .05 seconds of additional time delay compared with this experiment.

The dynamics for P7 were evaluated three times; twice by Pilot A and once by Pilot B. The first evaluation by Pilot A resulted in a rating of 4. The comments were "slow initial response, overcontrolled final", "no steady PIO", and "overcontrol in flare. Wanted to put in small input and see what resulted, didn't do it and was overcontrolling a little". The slow initial response is understandable, since the dynamics contained a 4 rad/sec stick prefilter. Pilot A's second evaluation was less critical; "didn't see much delay in nose", "more positive control of the nose than in previous configuration (P4A)", and, in summary, "very good, rating 1 to 2". A single complaint was; "slightest bit sluggish, nose a bit quicker than was in previous configuration (P4A)". The final second rating for P7 by Pilot A was 2. This rating is optimistic when viewed in the context of the first evaluation. Pilot B's evaluation was more akin to the first evaluation of Pilot A. His rating was a 4 and his comments were "tendency to overcontrol pitch corrections" and "too much pitch axis sensitivity". In summary, "little too sensitive. Tendency to overcontrol. Gross movement no problem, minor but annoying deficiencies." The overcontrol problem was noticed but no initial lag tendencies were commented upon. If the second rating of Pilot A is regarded as anomalous, the ratings and comments are consistent.

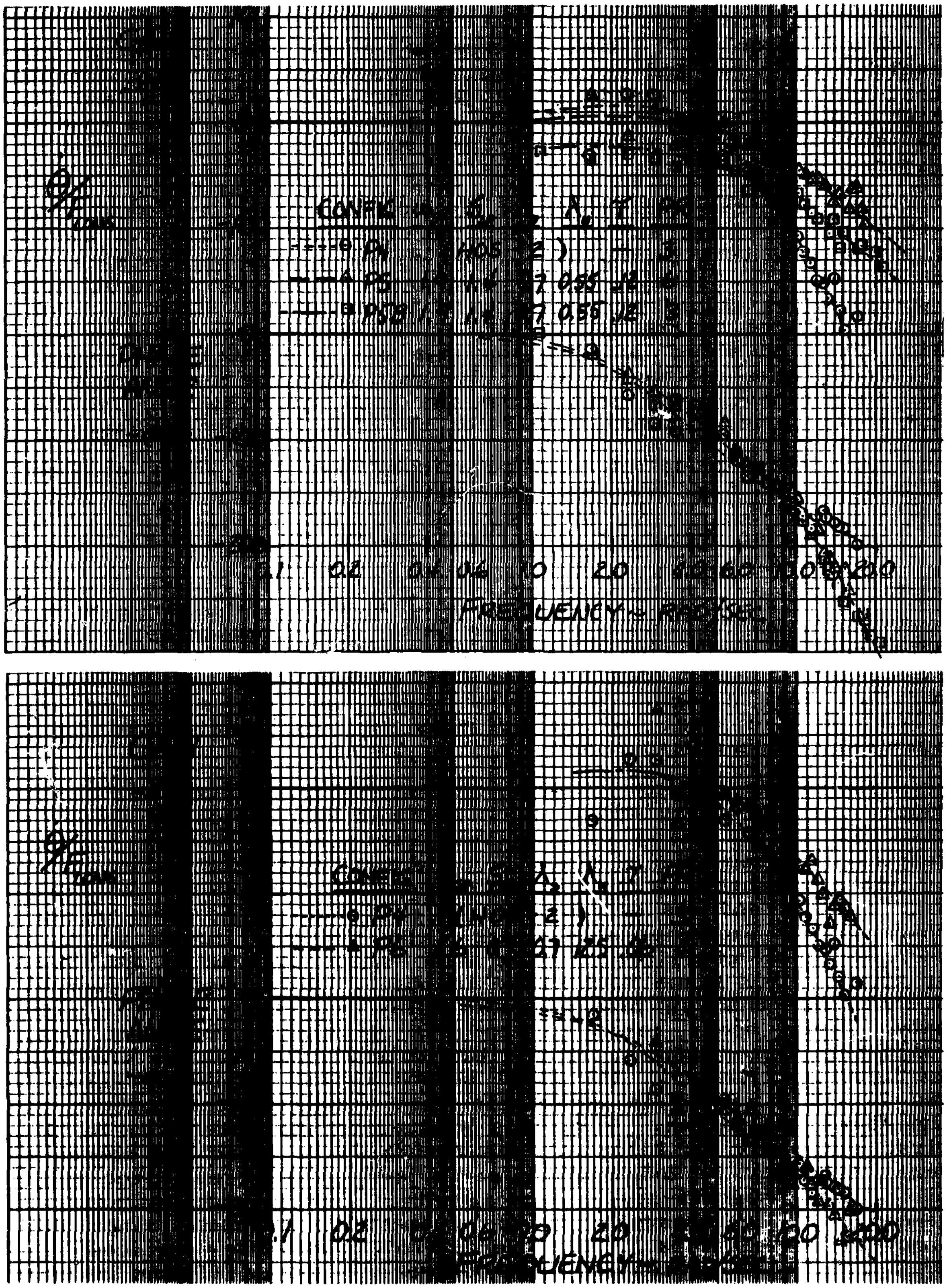


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Figure C-2. Effect of High Frequency Gain Match on Pilot Rating

The L_α fixed equivalent system, P8, was evaluated twice by Pilot A and the L_α free equivalent, P9, was flown once by Pilot A. Both times the P8 configuration was rated 5 with the remark that it could be 4 to 5. The P9 rating was 3. The 4 rating for P8 compares well with the ratings for P7. Inspection of the Bode plots in Figure C-3 shows that the dynamic characteristics of P7, P8, and P9 are similar. In general, the same descriptive comments were used by the pilot for the high order and the equivalent low order systems, "tendency to overcontrol pitch corrections".

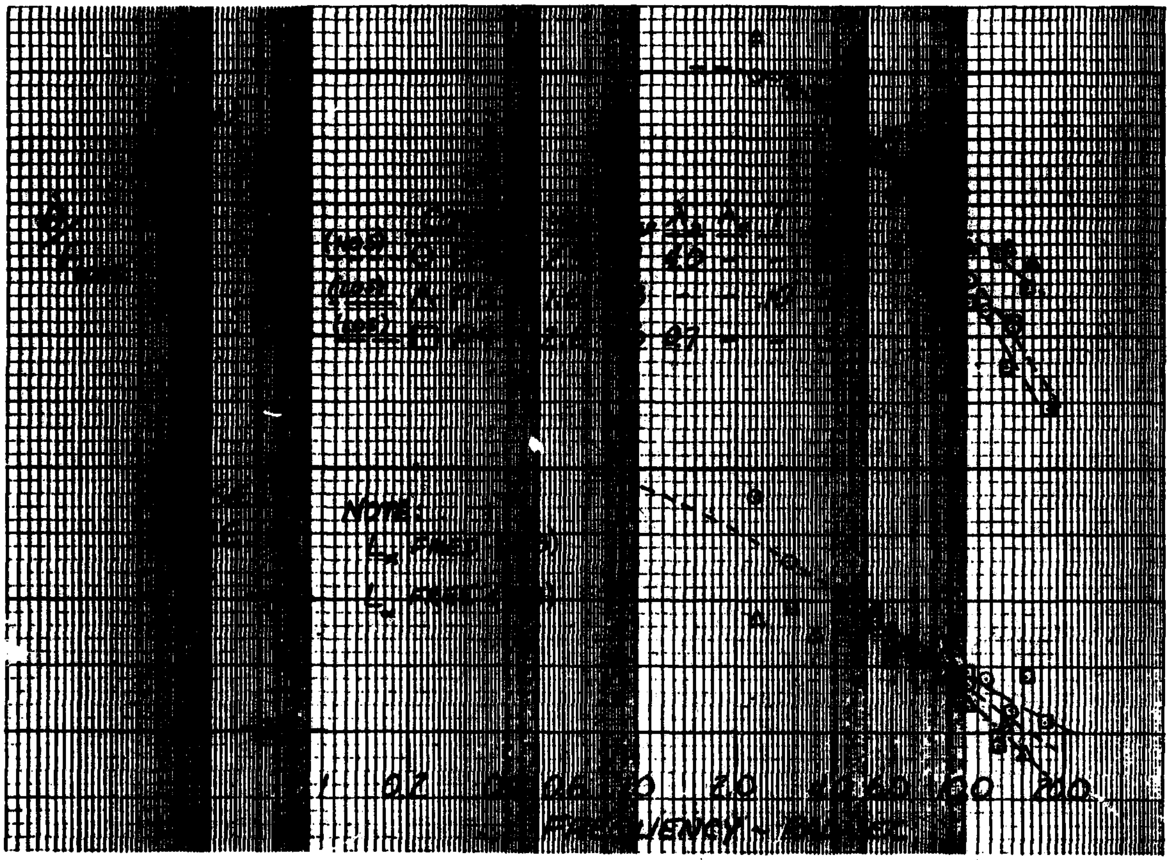

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Figure C-3. Equivalent Low Order Longitudinal Systems

<u>High Order System #4 (P11, P11A)</u>. Equivalent; P12 (L_α Fixed)

P11 was evaluated once each by pilot A and pilot B. Pilot A experienced a "small PIO" for the large offset, and gave a rating of 6. Pilot B felt that the touchdown point was "not good in spite of working hard" and awarded a rating of 4. Pilot A also twice evaluated the high order system with an added pure time delay (P11A) of .05 seconds to simulate more closely the LAHOS configuration which contained the series feel system. The ratings were 7 and 6 for P11A. The rating of 7 was due to a PIO.

The L_α fixed equivalent system, P12, was evaluated twice by pilot A and twice by pilot B. The ratings were 7 and 9 for A and 9 and 5 for B. The 5 rating for B is covered in the discussion of pilot technique in VI-1.a, and should be disregarded. The average rating (5.7) for the high order system is therefore noticeably different from the equivalent system average (7.5). The equivalent system caused more pronounced PIO tendencies. Since the mismatch function is essentially zero in the .1 to 10 rad/sec range, the pilot clearly is sensitive to some other phenomenon, possibly the additional gain rolloff above 10 rad/sec, Figure C-4.

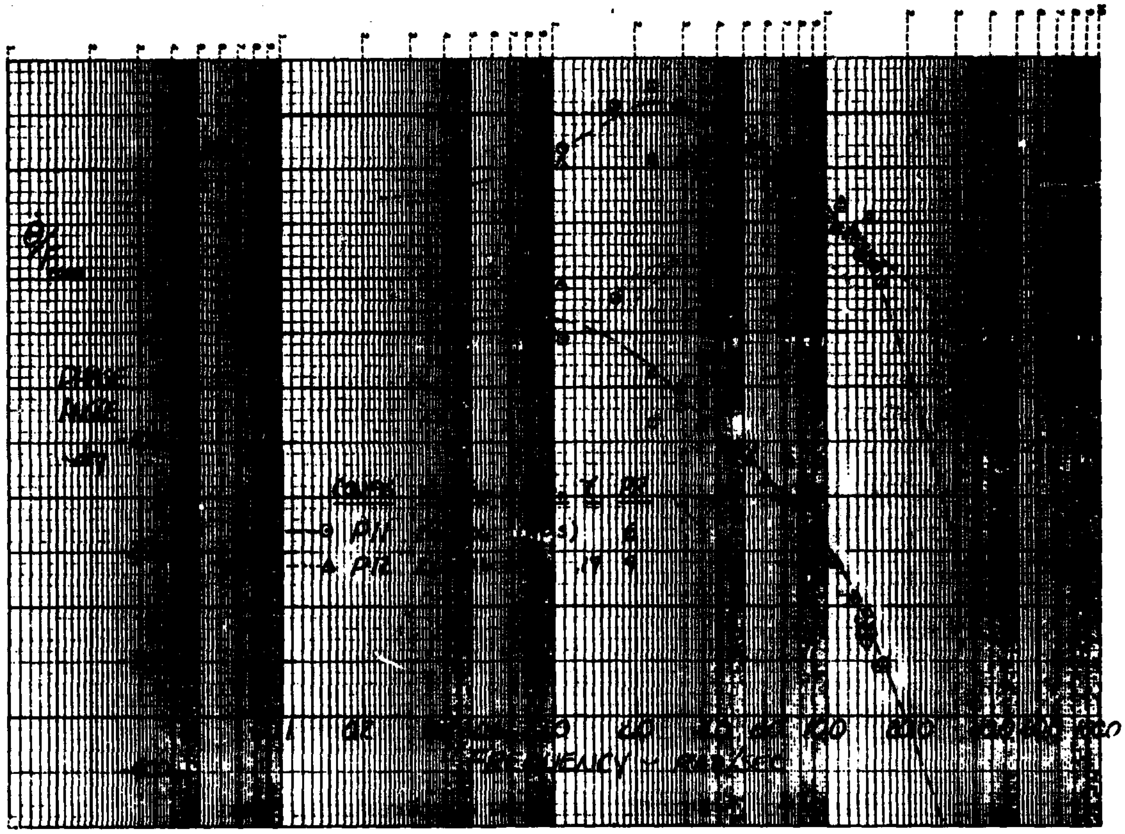

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Figure C-4. Effect of Gain Roll-Off at High Frequency

<u>High Order System #5 (P13, P13A)</u>. Equivalent; P14

Pilot A though experiencing a small overcontrolling tendency in flare, gave a rating of 3 to P13. The added .05 seconds delay of P13A degraded the rating to 6 due to a small, fairly quick PIO. (The PIO actually was around 1 cycle/second which is typical.) For the L_α-fixed equivalent, P14, the rating was 5, though the pilot considered awarding a 4. Small amplitude oscillations were evident during the flare.

On this flight, the first three configurations evaluated were P13, P15 and P14 in that order. After P14, the safety pilot asked for a direct comparison between P13 and P14.

Safety pilot (SP); "while we're going around here, do you recall the first airplane you flew, at all?"

Evaluation pilot (EP); "Yes, I had no problem."

SP; "How would you compare the first with the third, those two?"

EP; "On the first one I was overcontrolling a little bit - I couldn't feel the lag and it was just a little bit more theta (pitch) than I wanted, but there were no oscillation tendencies at all. The one that I just flew, it was a little bit more of an overcontrol than before and I was having to take back motions quickly in the other way and was going into a quick oscillation.

The aircraft didn't feel that much different until I got into the flare, and then there was a definite difference in the two, there."

Since the difference between the two configurations appears only at high frequencies (Figure C-5), this suggests that the pilot is sensitive to those differences.

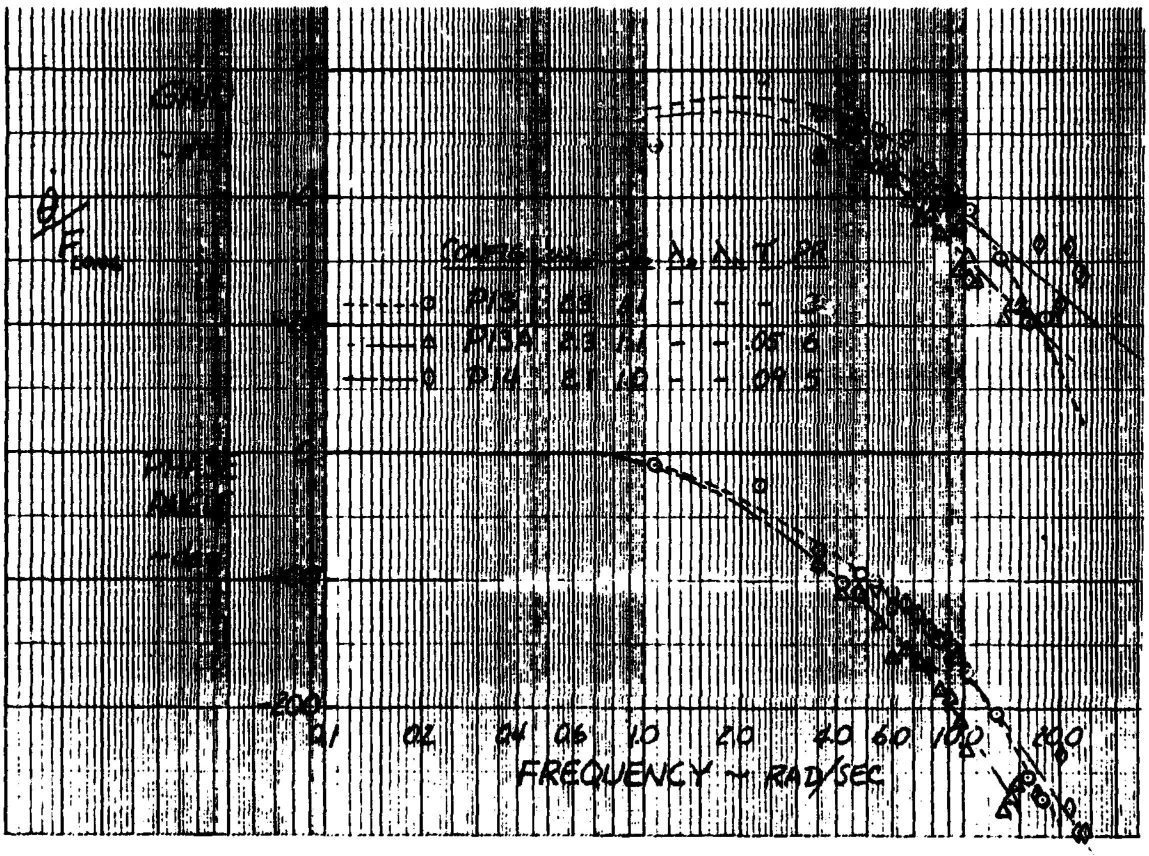

Figure C-5. Effect of Added Time Delay

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P13 was LAHOS configuration 4-7 with force commands (i.e., with reduced effective lag because the feel system was removed). Adding a delay of .05 sec to approximate the feel systems (configuration P13A) degraded the rating considerably to a 6 or "maybe a 7". The rating of 3 obtained for 4-7 in the LAHOS experiment is therefore almost certainly anomalous, as was suspected in the analysis of Reference 11 (Johnston).

<u>High Order System #6 (P15). Equivalents; P16, P16A, (L_α Fixed), P17 (L_α Free)</u>

P15, with a rating of 8 (Pilot A) and 9 (Pilot B) showed similar ratings to its equivalents; 8 for P16, 9 for P17 (both Pilot A). Comments refer to PIO tendency and slow pitch response for all the configurations. Configuration P16A had the delay reduced by .02 seconds and pilot B awarded it a 5. However, the safety pilot considered this rating to be optimistic, and Pilot C awarded 7 to this configuration. Of more interest for P16A is Pilot B's difficulty with the approach, which, rated an 8 or 9, was clearly more troublesome than the actual landing. No explanation is immediately evident for this. The time history shows PIO tendencies for both Pilot C and B.

P15 was a sluggish configuration with considerable high frequency lag. It produced a slow PIO (around 2 seconds per cycle) in Pilot A's evaluation, with complaints such as "initial response very slow; overcontrolled final response". The stick force traces show gross, spiky inputs with a periodic content around 2 sec/cycle, in spite of the pilot's efforts to "be very careful and smooth: avoid resorting to a bang-bang control". Pilot B experienced continuous PIO. The L_α fixed equivalent, P16, obtained the same rating and comments as P15, but the P16 stick force trace is less "spiky" in character. P17, the L_α free equivalent, exhibited handling characteristics similar to P15 and the pilot had the most difficulty in negotiating a landing. The frequency response comparisons are shown in Figure C-6.

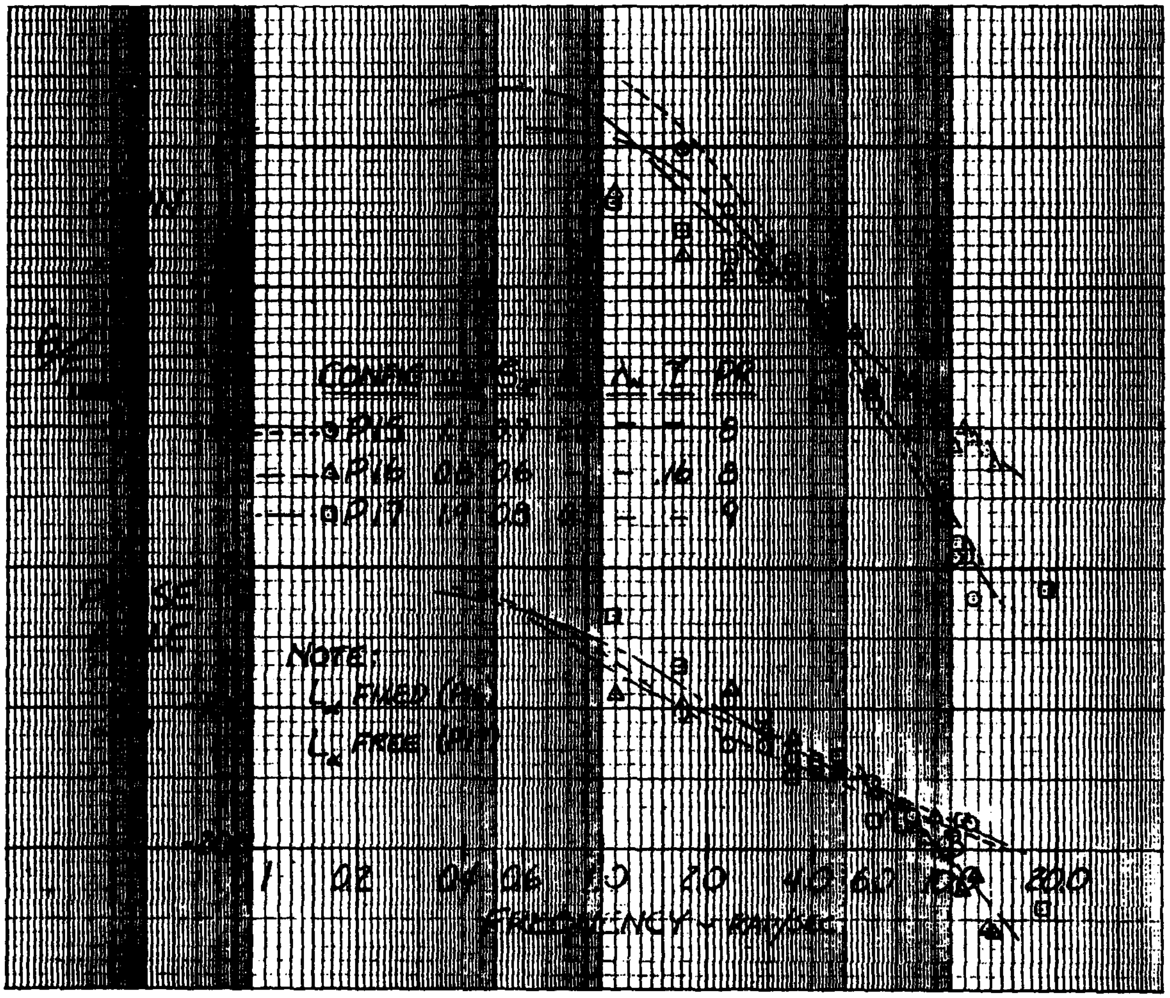

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Figure C-6. Equivalent Low Order Systems, Level 3

<u>Lateral Equivalents</u>:

<u>High Order System #1 (L1)</u>. Equivalent; L2

The ratings and comments were very similar for these two configurations. The pilot debated between ratings of 4 and 5 for L1, and 3 and 4 for L2. The initial response was too sensitive or abrupt, but the dynamics then tended to be somewhat sluggish. Making a direct comparison, the pilot considered the two configurations similar, but the L2 forces appeared a little heavier. Because the ratings and comments were similar, no response analysis was prepared from the flight data. A comparison is shown in Figure C-7, for the analytical response characteristics for L1 and L2.

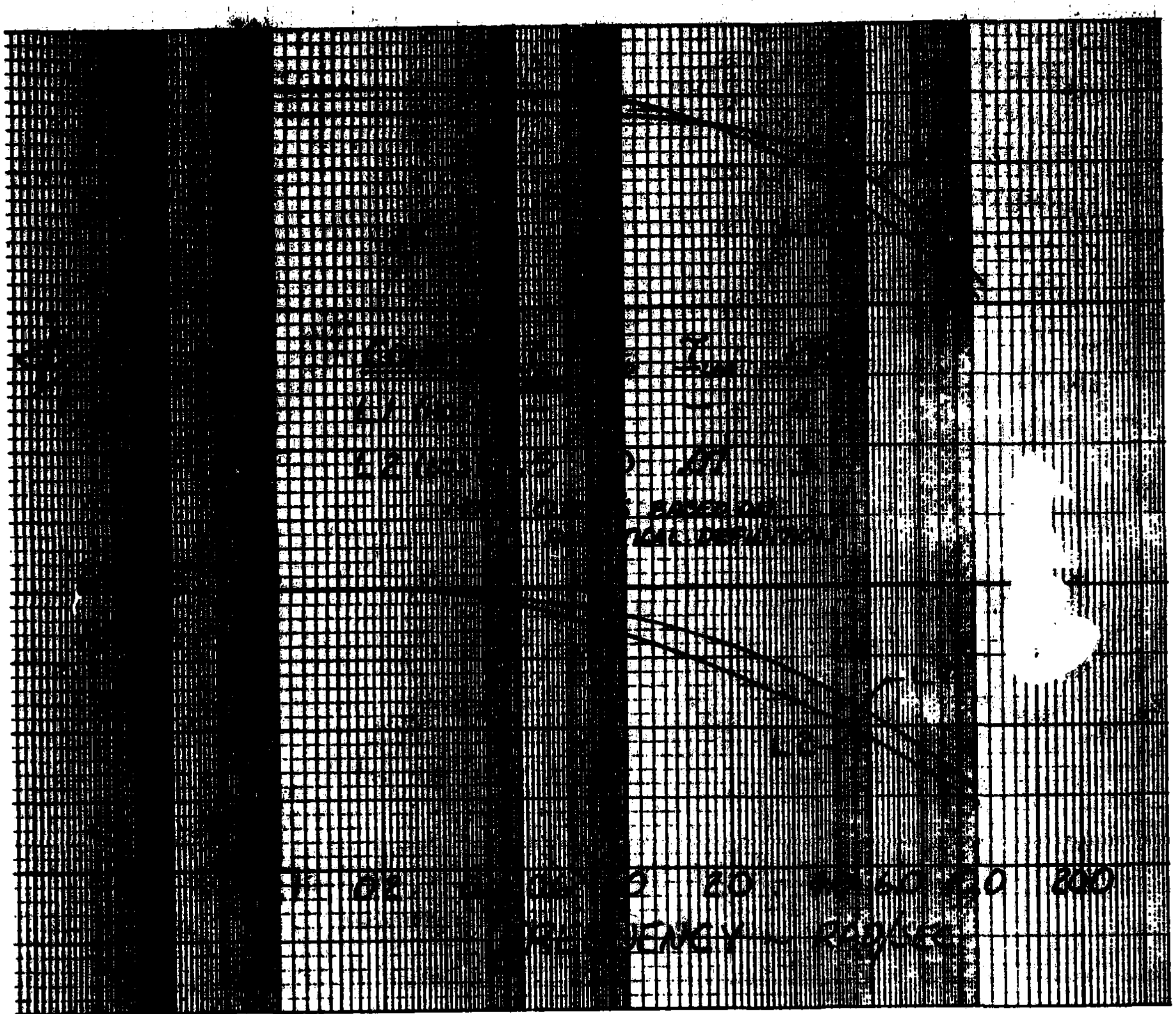
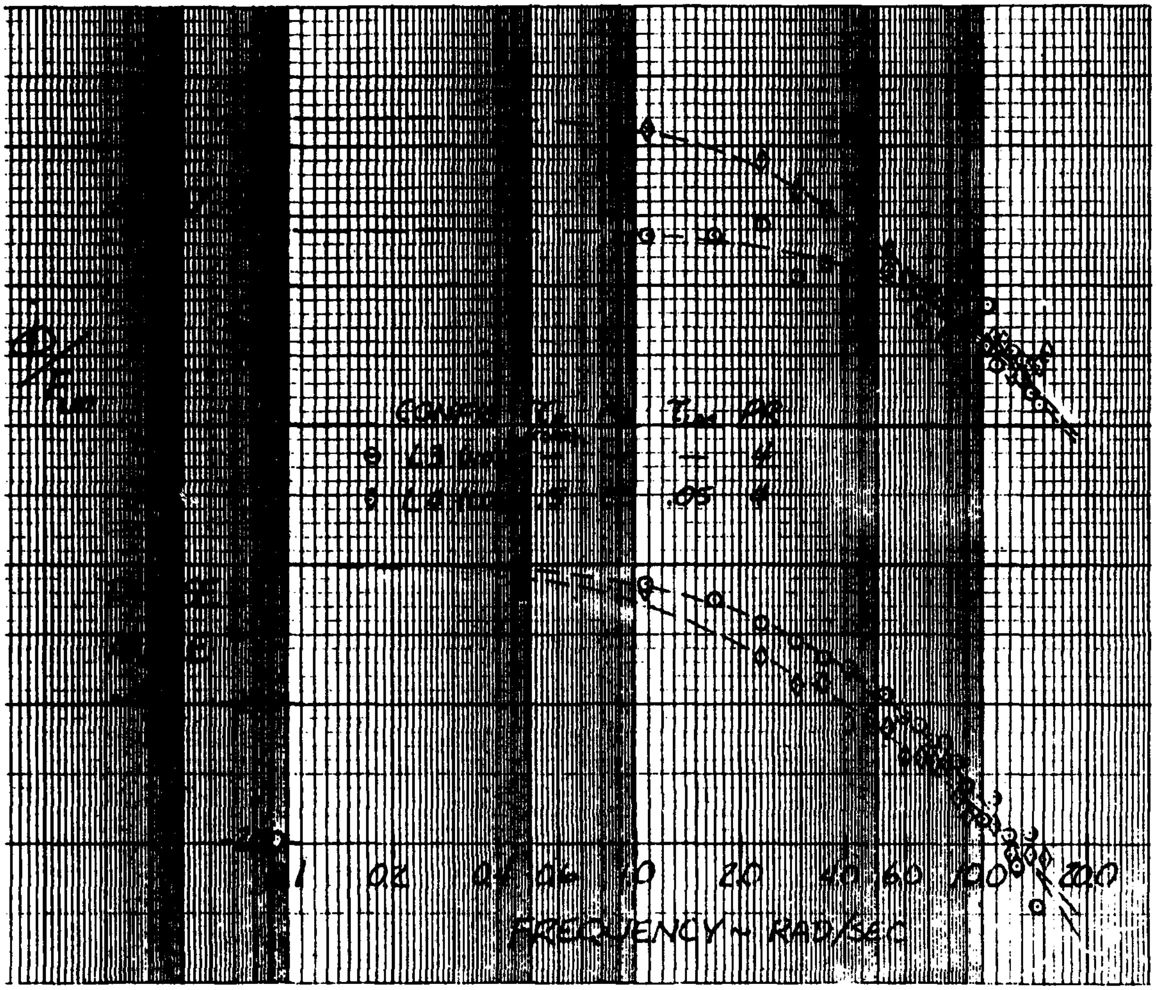


Figure C-7. Equivalent Low Order Lateral System

<u>High Order System #2 (L3)</u>. Equivalents; L4, L4A

The ratings are similar for all three configurations (4, 4, and 3 for L3, L4 and L4A respectively) but the comments indicate significant differences. L3 had a slow initial response, whereas L4 and L4A exhibited sensitivity. The steady state gain was higher for both the equivalents so it is possible that a lower gain would produce closer equivalence of comments. L3 is compared with L4 in Figure C-8. L4A Flight test data was not analyzed, since pilot comments and ratings were similar to L4.



GP13-0824-31

Figure C-8. Effect of Steady State Gain

"High" Order System #3 (L6). Equivalent L4

L6 was an excellent aircraft, with a rating of 2 overall and 1 for the lateral dynamics alone. L4, with a rating of 4, was noticeably different, with initial sensitivity apparently degrading otherwise good characteristics. Therefore, though the rating is on the extreme of pilot scatter, there is an indication of a tangible difference. Figure C-9 shows that the roll response characteristics of L6 and L4 are similar; but that the L4 has higher command gain than L6, while for the same frequencies the phase angle is less for L4 than for L6. The combination of high gain and reduced phase angle roll-off degrades pilot rating of L4 and results in pilot comment - too sensitive and abrupt initially.

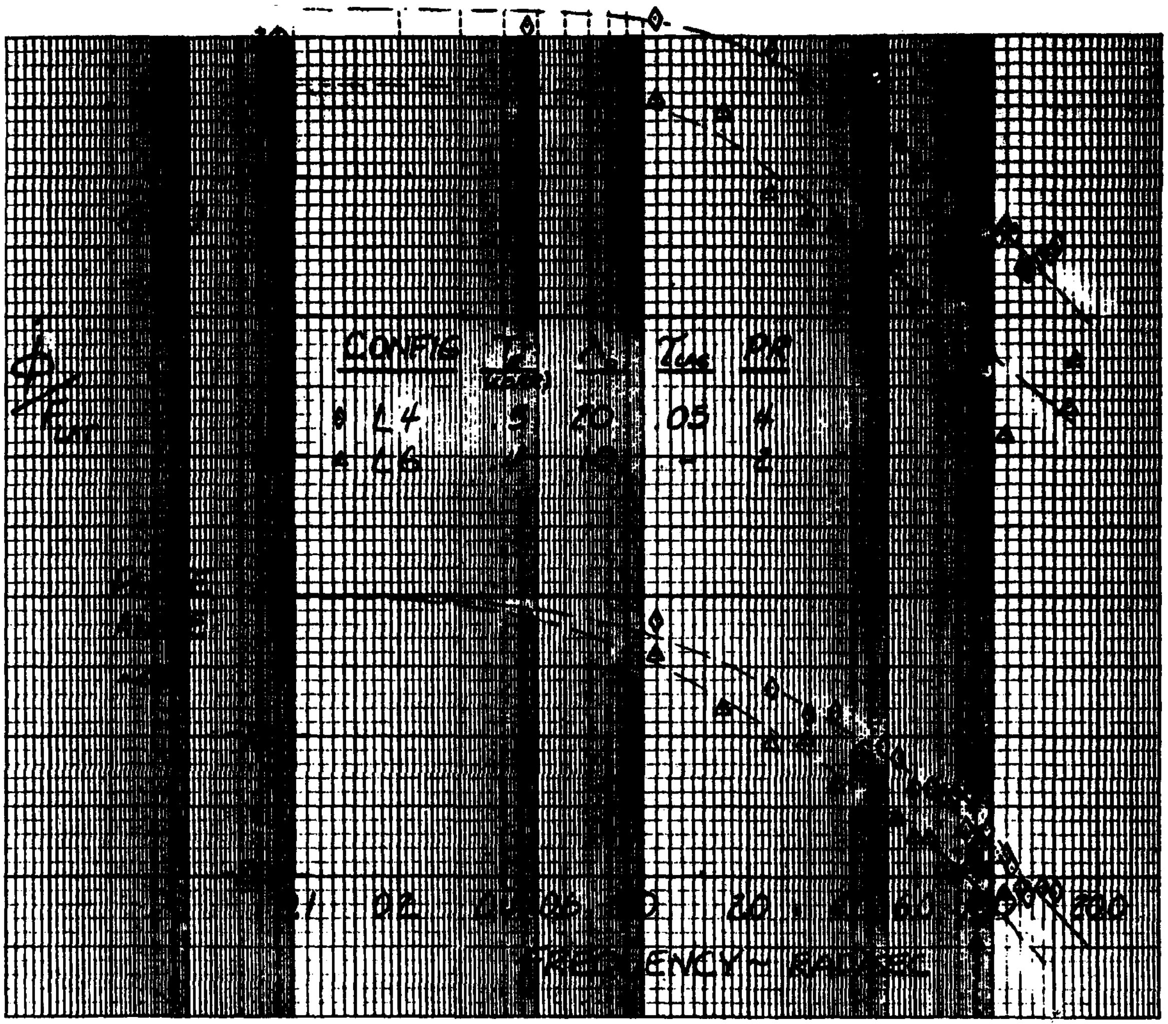
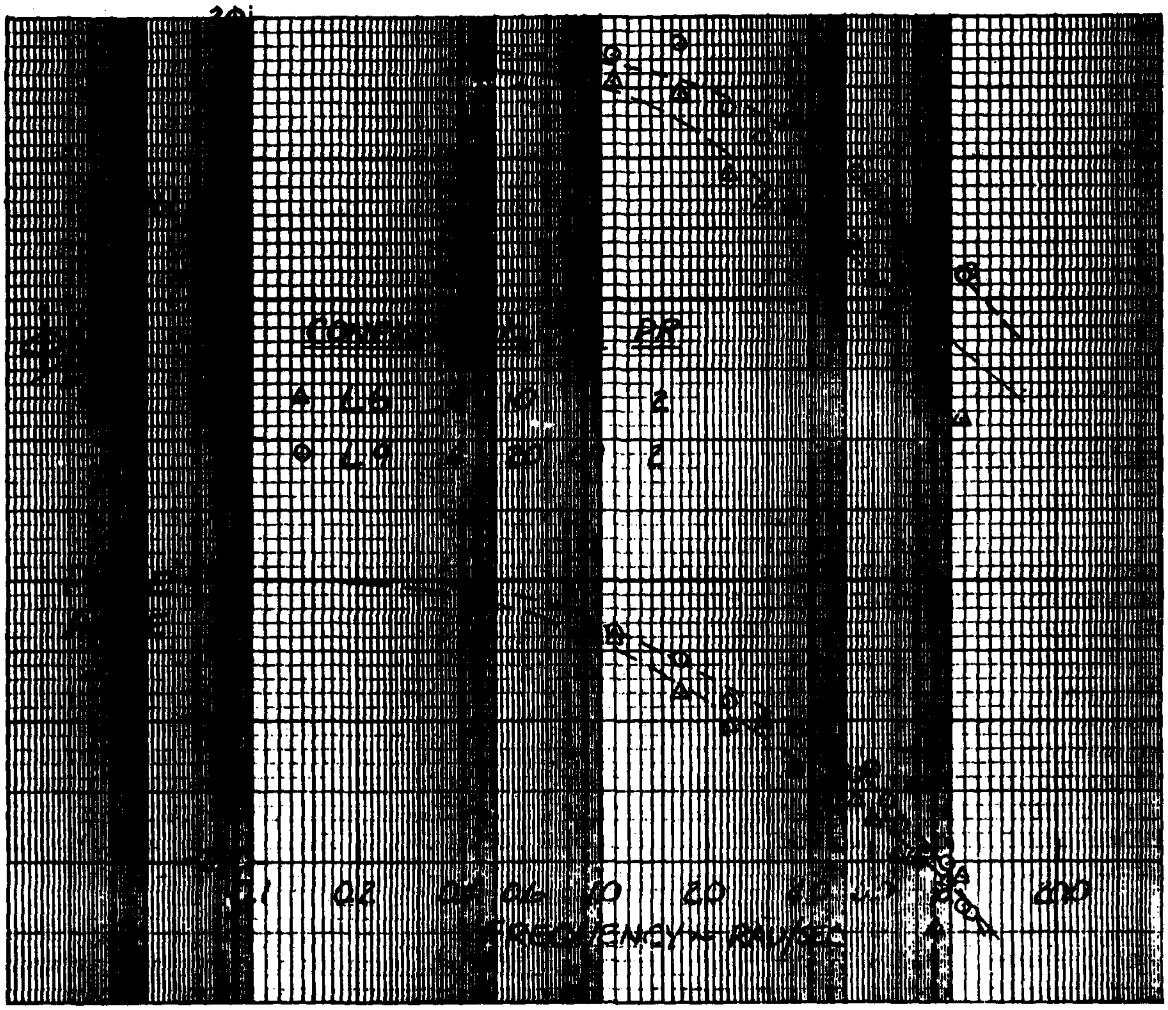


Figure C-9. Effect of Gain Difference and Time Delay Combination

<u>"High" Order System #4 (L6)</u>. Equivalent L9

Good equivalence was demonstrated, with very similar comments. Both aircraft received a rating of 2. However, L9 had "little lag in initial response." which was not noted for L6. Figure C-10 shows that the frequency response characteristics of L6 and L9 are similar.



GP13-0324-30

Figure C-10. Effect of Time Delay, Lag Time/Lag Time Plus Pure Time

APPENDIX D

ANALYTICAL COMPARISONS FOR HIGH AND LOW ORDER EQUIVALENT SYSTEMS

The longitudinal and lateral analytical rate response characteristics are compared using both Bode plots and step time history matches. The roots of the high and low order configurations, planned for the evaluation of the ESP, tabulated on the figures and in Tables 5 and 8 the body of this report, are analytical descriptions of each of the systems. As noted in Tables 5 and 8, the configurations with a time delay network circuit should have an additional time increment (.025 sec) to include equivalent delay for the Butterworth filters. The data in this Appendix have not been revised for the additional time increment, since parameters as presented are applicable for comparison purposes. Short-period pitch rate response is selected as the appropriate parameter for the longitudinal evaluations, and the roll rate response as the dominant factor for lateral analysis in the approach and landing task.

LONGITUDINAL SYSTEMS

The analytical pitch rate response and step time history matches for the longitudinal evaluations are shown in Figures D-1 thru D-20. There are two sets of matches. One exhibits the mismatch obtained by freeing the gain parameter, Figure D-1 through Figure D-10. This is the same as sliding the gain plots vertically to minimize the match. In the second set, Figure D-11 through D-20 the gains are held to the same nominal steady-state value of unity. This illustrates the contribution of gain to the mismatch. The equivalent parameters are otherwise unchanged. Phugoid dynamics are excluded from the matches shown because there is sufficient frequency separation between the phugoid and the simulated short period frequencies. Inclusion would not alter the short period results.

The roots of the high and low order configurations (P1, P2, etc.) are defined on the plots. First order roots are shown explicitly or in parenthesis. Second order pairs are shown in brackets, with the damping ratio and undamped natural frequency in radians per second. The comments are the most salient from Appendix A. The ratings are Cooper-Harper as reported from the flight evaluations.

The term 'cost' is the MCAIR mismatch function value, which has been defined in Section II.

LATERAL SYSTEMS

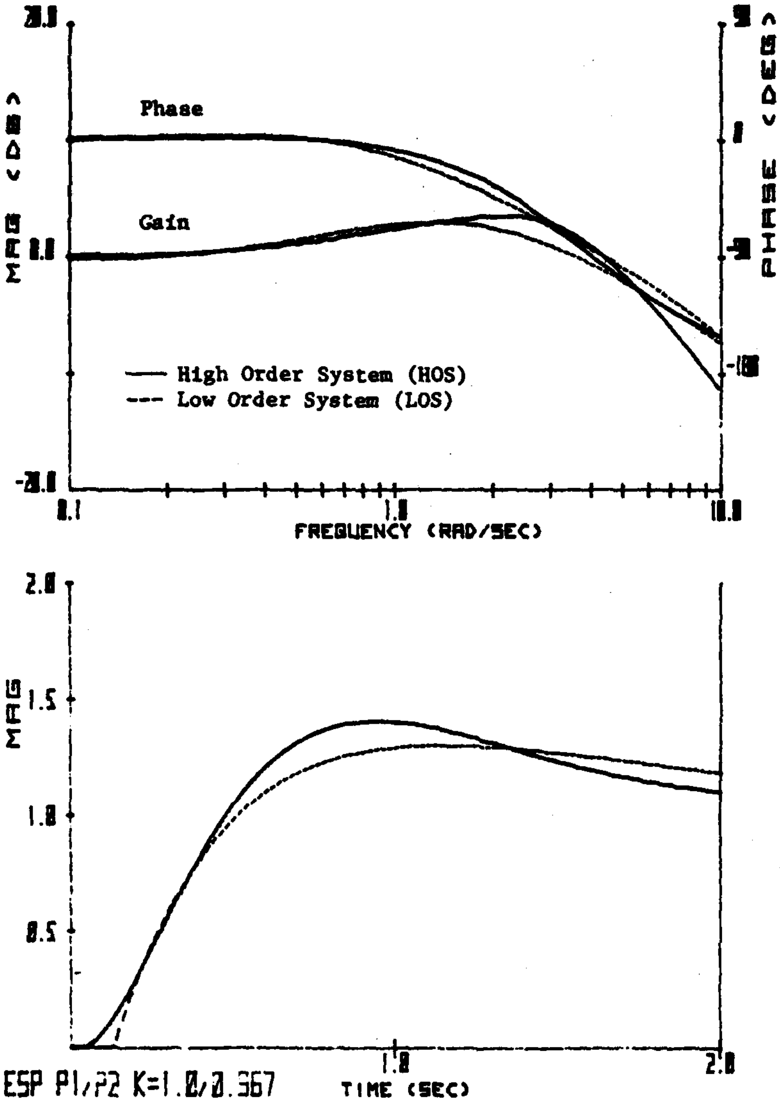
The following are response characteristics, Bode and roll rate step time histories for the lateral ESP data. Similar to the longitudinal responses, there are two sets of comparison plots.

The first, Figures D-21 through D-30, illustrates the effect of minimizing mismatch by freeing the gain. In the second set, Figures D-31 and D-32, the gains are held to the same nominal steady-state value of unity. Also, plots are presented for effect of control system lag and time delay with "short" τ_R, high roll damping (L5 through L11), in Figures D-33 through D-43. The effect of control system lag and time delay with "long" τ_R, medium roll damping (L12 through L61), is shown in Figures D-44 through Figure D-52.

As mentioned in the report, several instances of special combinations of lag and time delay mistakenly evolved and are included in the data summary. When these analytical data are compared with the frequency response characteristics plotted in Appendix E, the special combinations are evident.

PILOT COMMENTS

P1 - Teeniest Bit of Over Control but Predictable. PR = 2.
P2 - Little Bit of Over Control at Touchdown, Predictable Final Response. PR = 2.



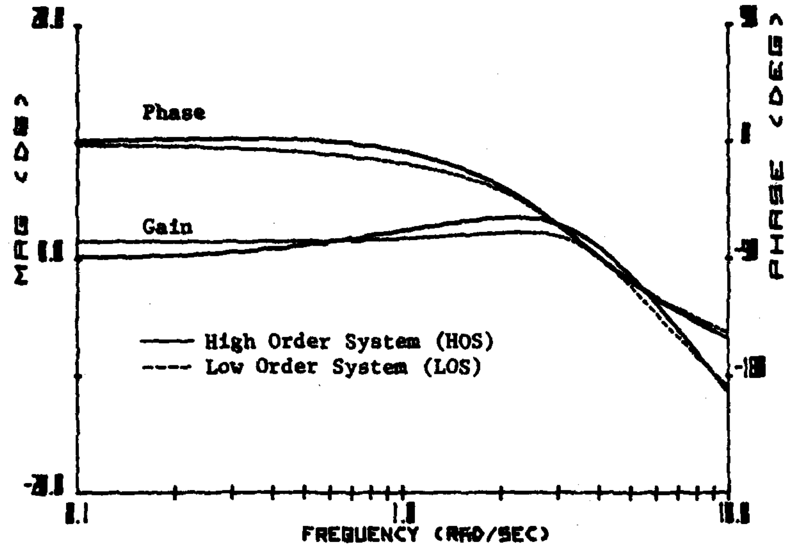
AIRFRAME		
	P1 HOS	P2 LOS
$\omega_{n_{sp}}$	3.21	1.50
ζ_{sp}	0.70	1.10
$1/\tau_{\theta_2}$	0.55	0.50
τ	0	0.12
GAIN(K)	1.0	0.962
COST = 42.5		

CONTROL SYSTEM
P1 (HOS)
$\dfrac{(20)\ (5)\ (2.5)}{(16.4)(6.7)(4.1)(.76)}$

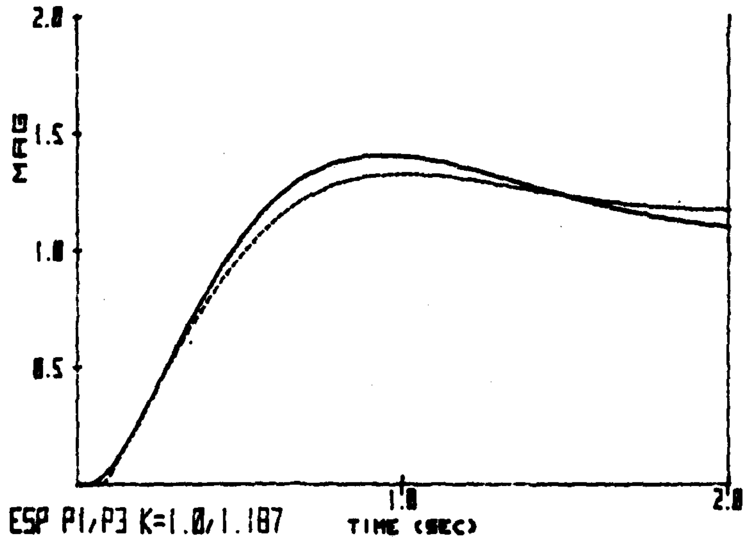
Figure D-1 Analytical Characteristics - Pitch Rate Response and Step Time History

PILOT COMMENTS

P1 - Teeniest Bit of Over Control but Predictable. PR = 2.
P3 - Little Over Control in Flare. PR = 3.



AIRFRAME		
	P1 HOS	P3 LOS
$\omega_{n_{sp}}$	3.21	3.50
ζ_{sp}	0.70	0.60
$1/\tau_{\theta_2}$	0.55	6.30
τ	0	0.07
GAIN(K)	1.0	1.187
COST = 29.3		



CONTROL SYSTEM

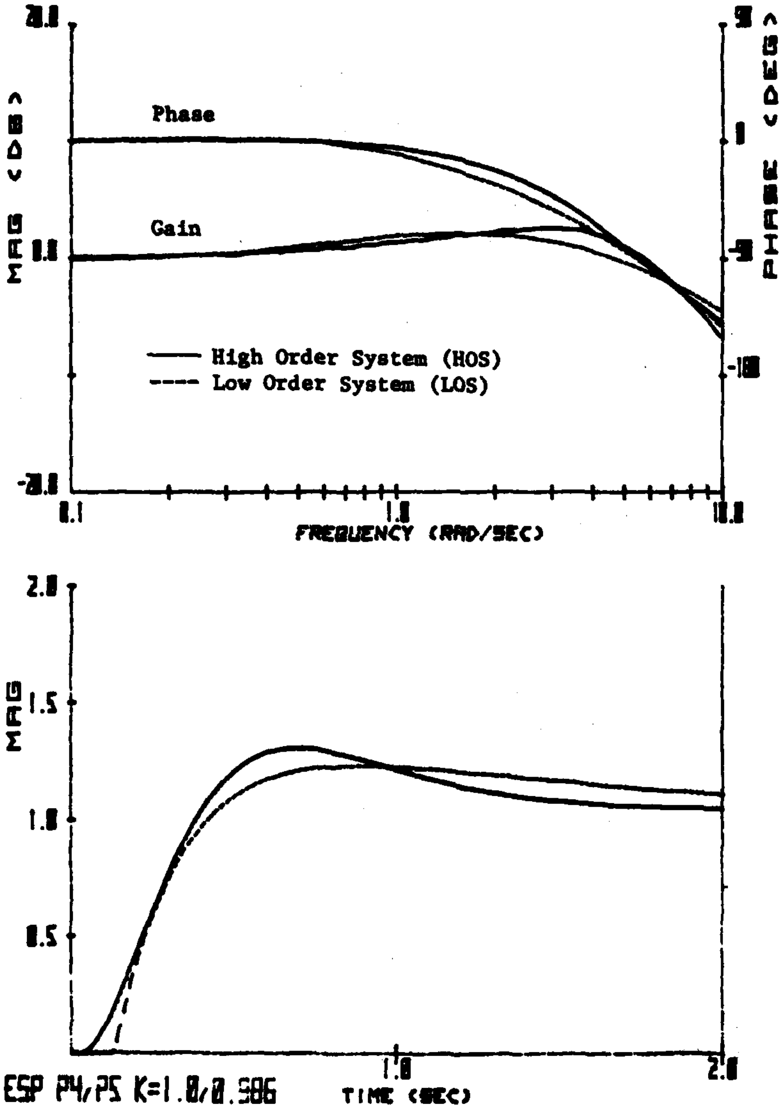
P1 (HOS)

$$\frac{(20)(5)(2.5)}{(16.4)(6.7)(4.1)(.76)}$$

Figure D-2 Analytical Characteristics - Pitch Rate Response and Step Time History

PILOT COMMENTS

P4 - Nice Until Flare then Noticed Lag. Slight Over Control. PR = 3.
P5 - Over Controlled Final Response, Quick Response. PR = 6.



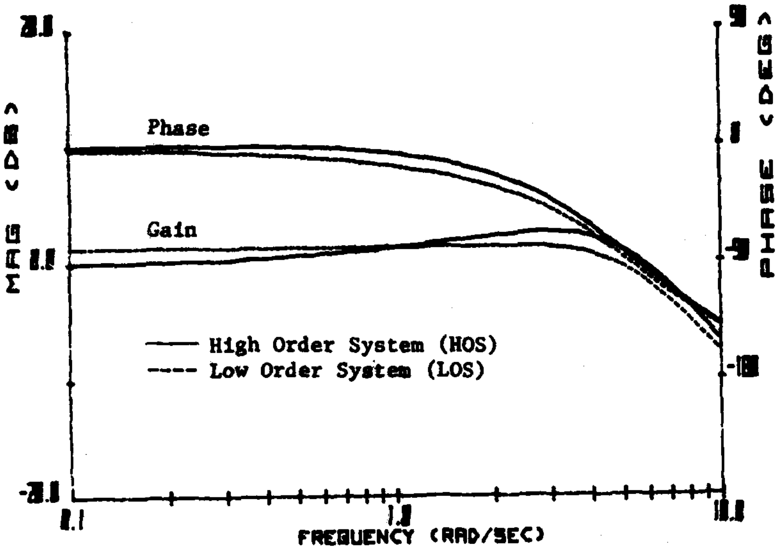
AIRFRAME		
	P4 HOS	P5 LOS
$\omega_{n_{sp}}$	4.57	1.90
ζ_{sp}	0.81	1.40
$1/\tau_{\theta_2}$	0.55	0.55
τ	0	0.12
GAIN(K)	1.0	0.986
COST = 23.2		

CONTROL SYSTEM
P4(HOS)
$\frac{(2.5)(20)}{(12.3)(.64)(6.7)}$

Figure D-3 Analytical Characteristics - Pitch Rate Response and Step Time History

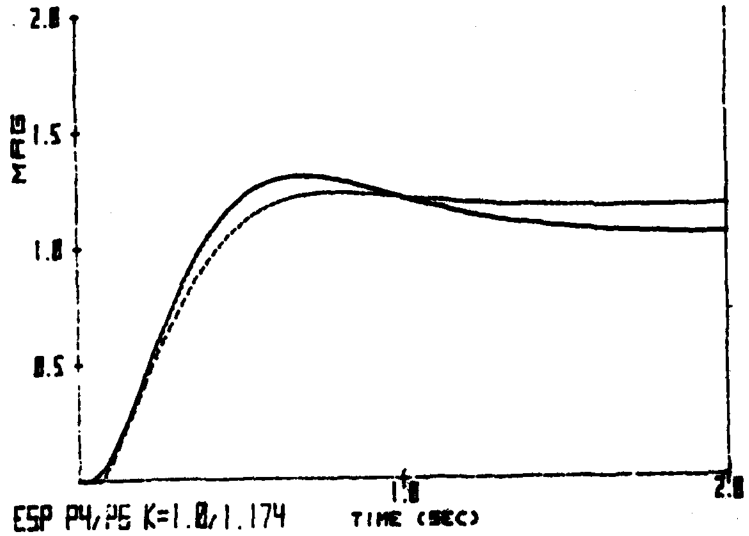
PILOT COMMENTS

P4 - Nice until flare then noticed lag. Slight over control. PR = 3.
P6 - Little bit of lag then bit of over control. PR = 4.



AIRFRAME	P4 HOS	P6 LOS
$\omega_{n_{sp}}$	4.57	5.30
ζ_{sp}	0.81	0.70
$1/\tau_{\theta_2}$	0.55	12.5
τ	0	0.06
GAIN(K)	1.0	1.174

COST = 35.2



CONTROL SYSTEM

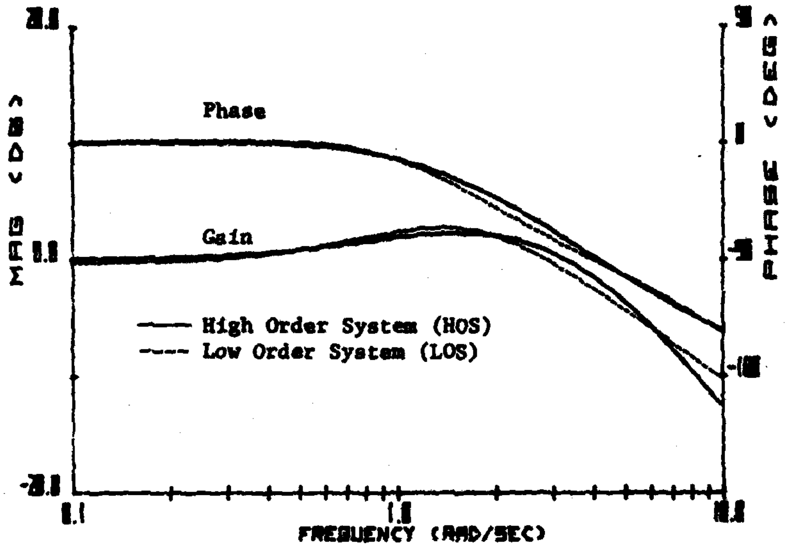
P4 (HOS)

$$\frac{(2.5)(20)}{(12.3)(.64)(6.7)}$$

Figure D-4 Analytical Characteristics - Pitch Rate Response and Step Time History

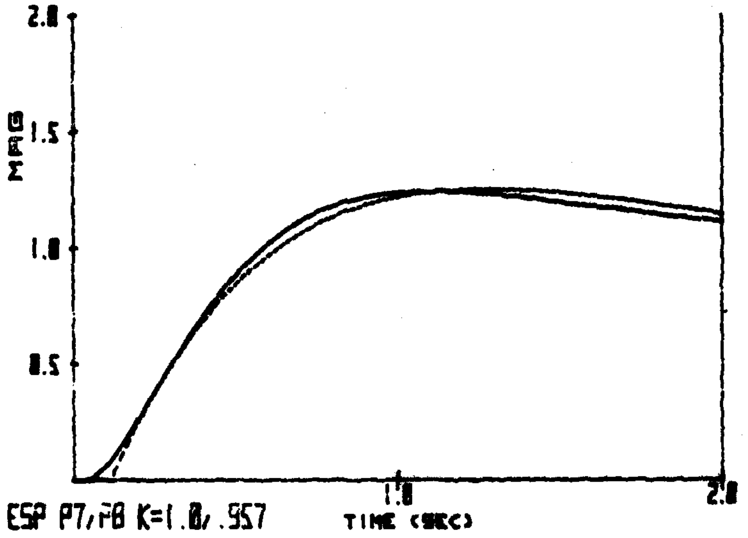
PILOT COMMENTS

P7 - Slow initial response, over controlled final. PR = 4.
P8 - Bit of lag in initial response and over control on final response, had to back out of loop a bit. PR = 5.



AIRFRAME	P7 HOS	P8 LOS
$\omega_{n_{sp}}$	2.30	1.60
ζ_{sp}	1.10	0.80
$1/\tau_{\theta_2}$	0.80	0.80
τ	0	0.10
GAIN(K)	1.0	0.957

COST = 15.0

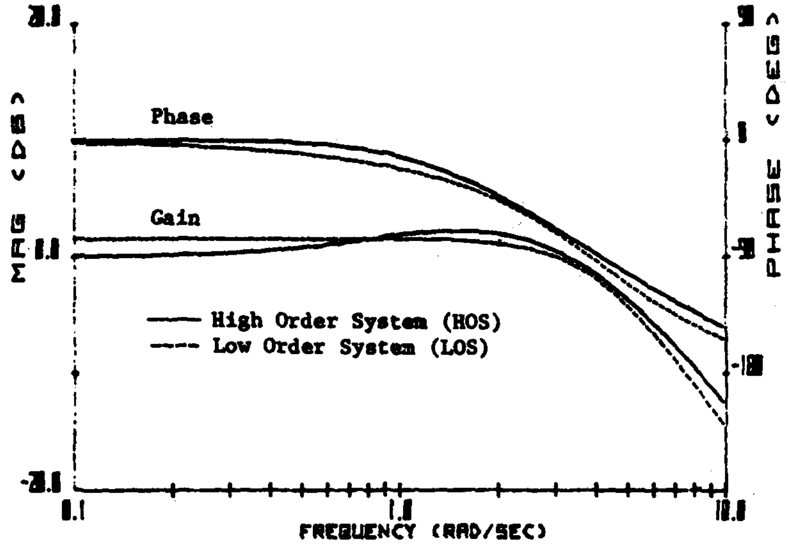


CONTROL SYSTEM
P7(HOS)
$\frac{1}{(S+4)}$

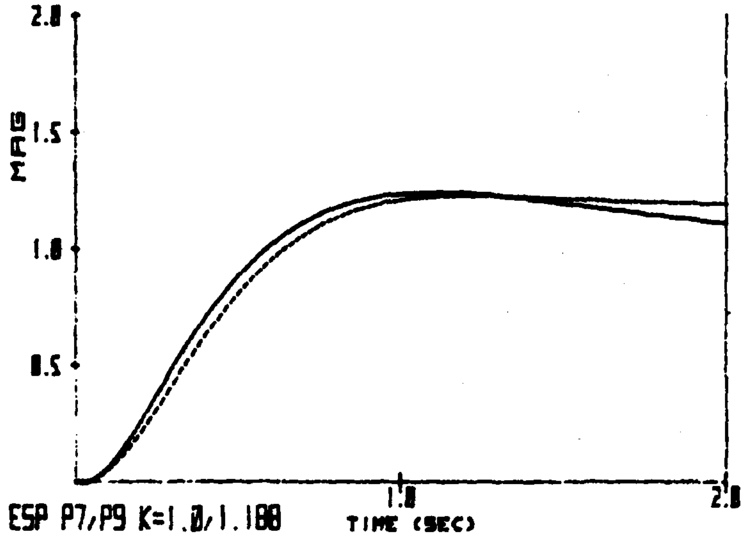
Figure D-5 Analytical Characteristics - Pitch Rate Response and Step Time History

PILOT COMMENTS

P7 - Slow initial response, over controlled final. PR = 4.
P9 - Over controlled a little in flare but a pretty good airplane. PR = 3.



AIRFRAME		
	P7 HOS	P9 LOS
$\omega_{n_{sp}}$	2.30	4.00
ζ_{sp}	1.10	0.75
$1/\tau_{\theta_2}$	0.80	0
τ	0	0
GAIN(K)	1.0	1.188
COST = 40.2		



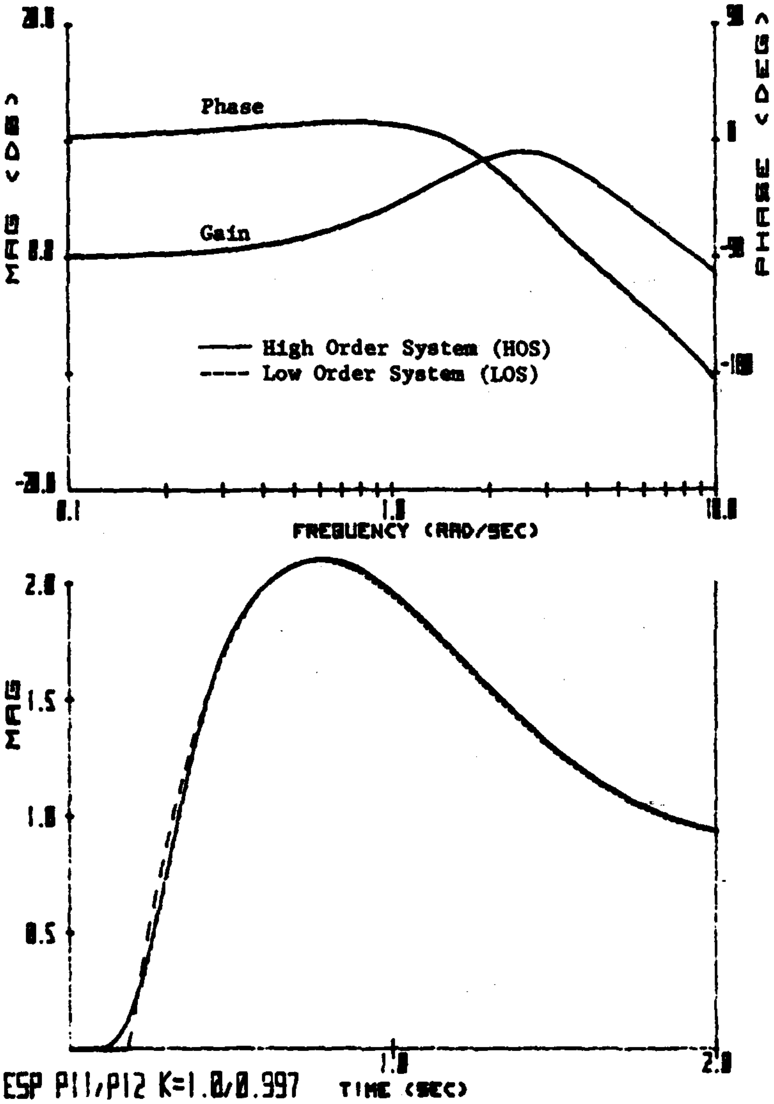
CONTROL SYSTEM
P7 (HOS)
$\frac{1}{(S + 4)}$

Figure D-6 Analytical Characteristics - Pitch Rate Response and Step Time History

PILOT COMMENTS

P11 - Tendency to over-control; got a small PIO, stayed in loop and was able to stay in control. PR = 6.

P12 - No problem until flare, had to back out of loop to land, fairly high frequency over-control. PR = 9.



AIRFRAME		
	P11 HOS	P12 LOS
$\omega_{n_{sp}}$	2.60	2.60
ζ_{sp}	0.60	0.60
$1/\tau_{\theta_2}$	0.80	0.80
τ	0	0.17
GAIN(K)	1.0	0.997

COST = 0.27

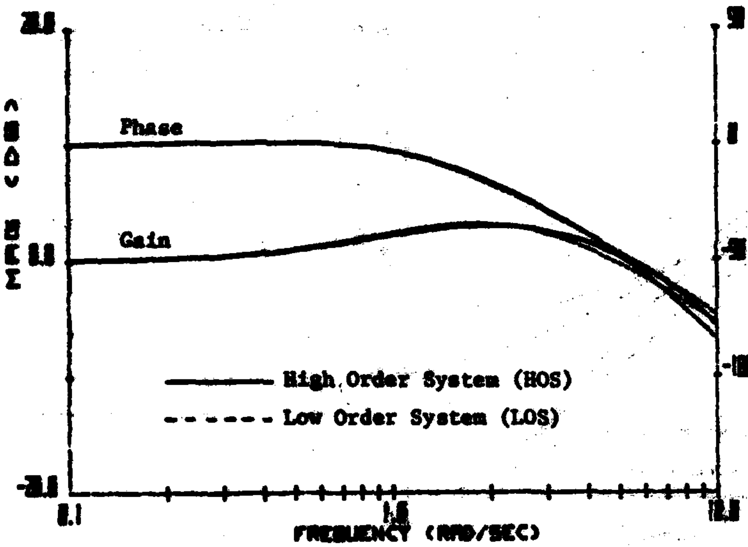
CONTROL SYSTEM
P11(HOS)
$\frac{1}{[.94;16][.38;16]}$

Figure D-7 Analytical Characteristics - Pitch Rate Response and Step Time History

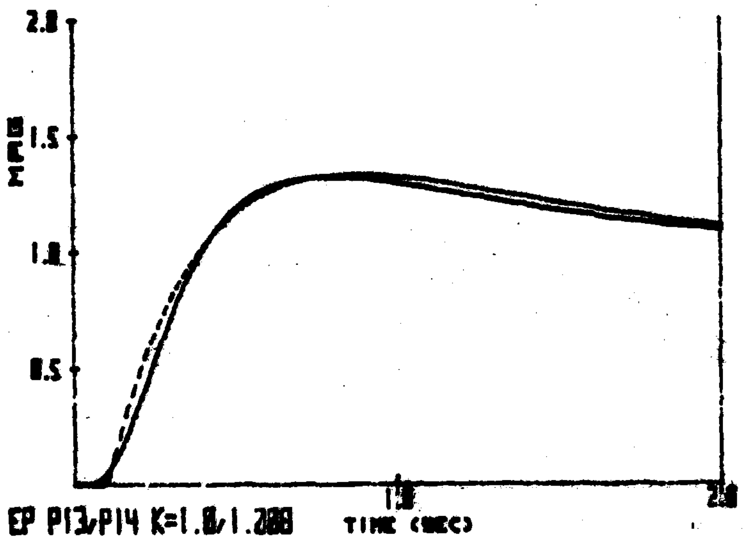
PILOT COMMENTS

P13 - Overcontrolled nose slightly in flare, pretty good airplane. PR = 3.

P14 - Problem in the final flare; very nice airplane until one tried to quickly move attitude. PR = 5.



Airframe	P13 HOS	P14 LOS
$\omega_{n_{SP}}$	2.30	2.10
ζ_{SP}	1.10	1.00
$1/\tau_{\theta_2}$	0.80	0.80
τ	0	0.09
GAIN(K)	1.0	1.008
COST = 11.8		



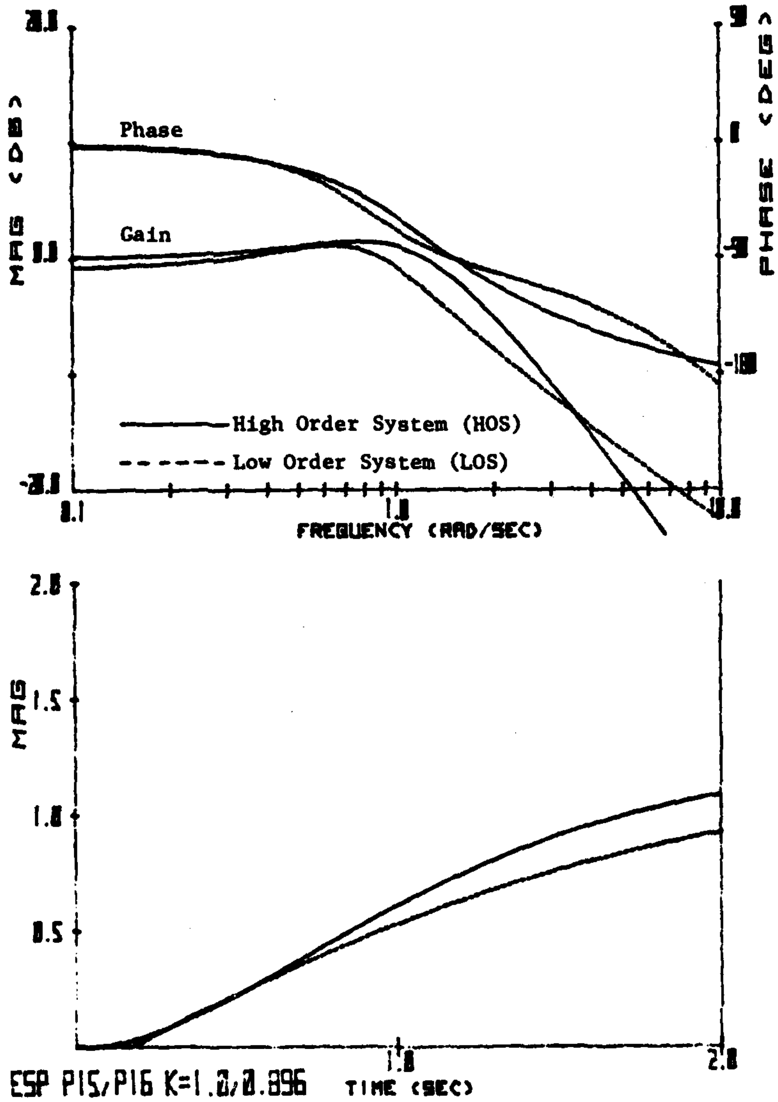
Control System
P13 (HOS)
$\frac{1}{[.7;\ 12]}$

Figure D-8 Analytical Characteristics - Pitch Rate Response and Step Time History

PILOT COMMENTS

P15 - Initial response very slow, overcontrol final response, aircraft lacked precision. PR = 8.

P16 - Initial response very slow, final response also slow, workload very high. PR = 8.



Airframe		
	P15 HOS	P16 LOS
ω_{nSP}	1.10	0.80
ζ_{SP}	0.70	0.60
$1/\tau_{\theta_2}$	0.80	0.80
τ	0	0.16
GAIN(K)	1.0	0.896
COST = 176.0		

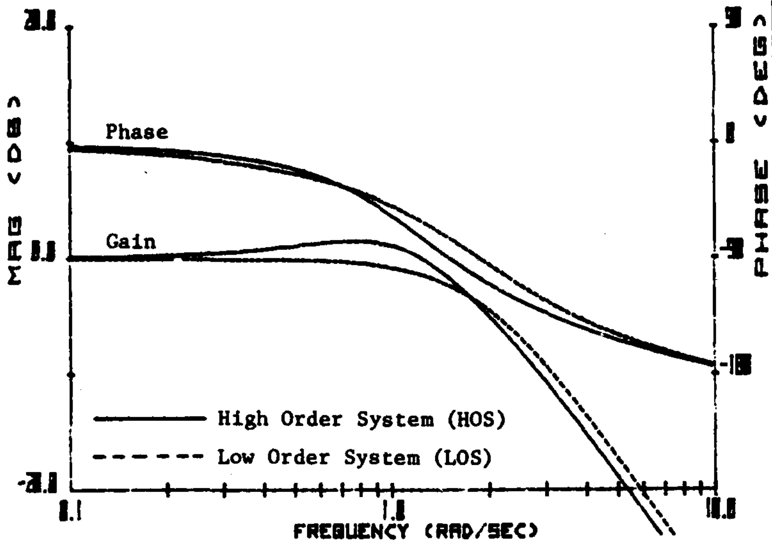
Control System
P15 (HOS)
$\frac{1}{(S + 2.0)}$

Figure D-9 Analytical Characteristics - Pitch Rate Response and Step Time History

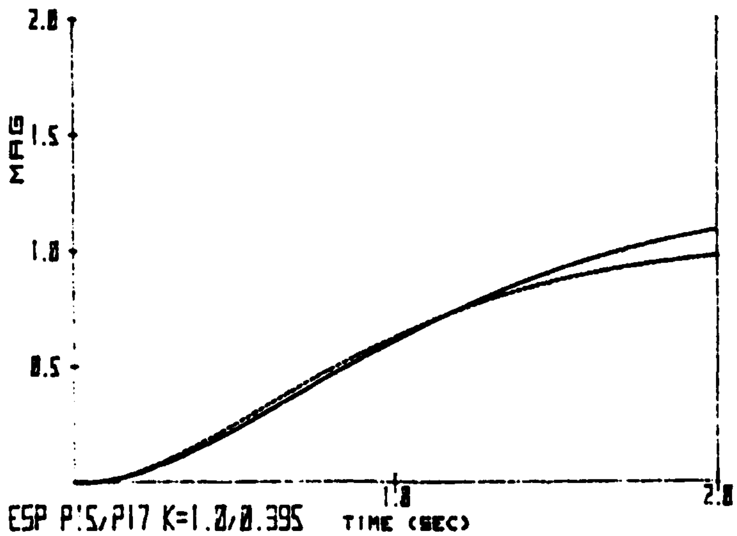
PILOT COMMENTS

P15 - Initial response very slow, over control final response, aircraft lacked precision. PR = 3.

P17 - Pitch attitude very slow, final response unpredictable. PR = 9.



Airframe	P15 HOS	P17 LOS
$\omega_{n_{SP}}$	1.10	1.90
ζ_{SP}	0.70	0.80
$1/\tau_{\theta_2}$	0.80	∞
τ	0	0
GAIN(K)	1.0	0.995
COST = 49.3		

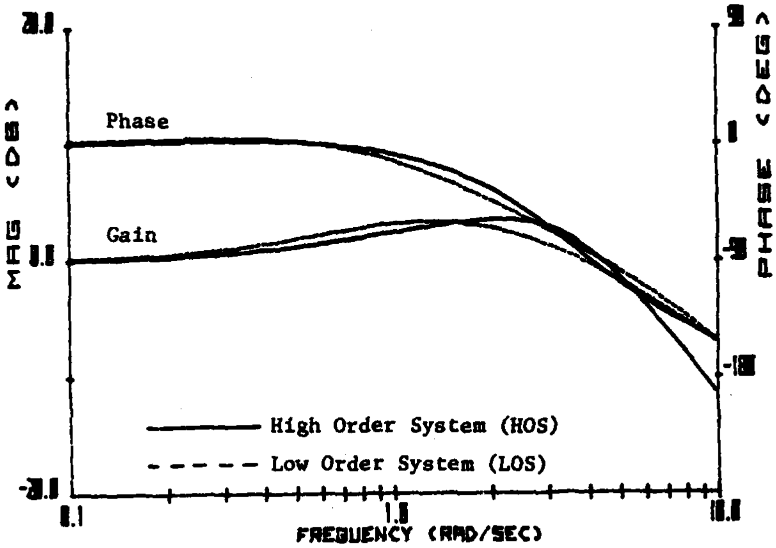


Control System
P15 (HOS)
$\frac{1}{(S + 2.0)}$

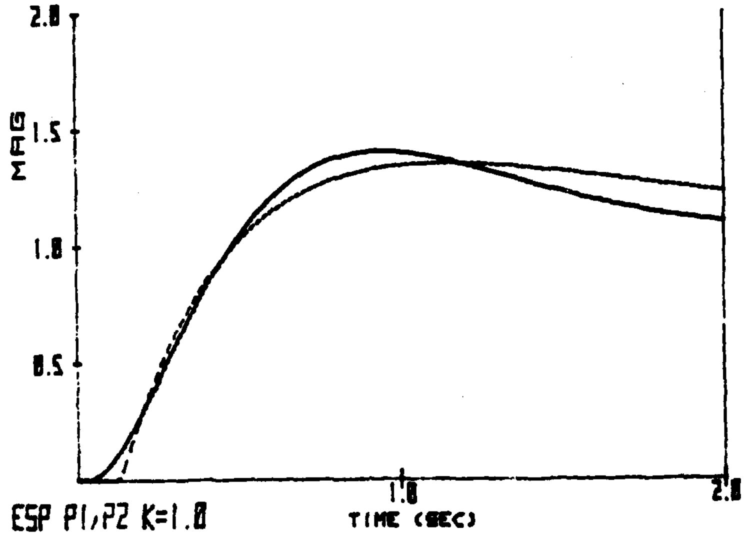
Figure D-10 Analytical Characteristics - Pitch Rate Response and Step Time History

PILOT COMMENTS

P1 - Teeniest bit of over control but predictable. PR = 2.
P2 - Little bit of over control at touchdown, predictable final response. PR = 3.



Airframe	P1 HOS	P2 LOS
$\omega_{n_{SP}}$	3.21	1.50
ζ_{SP}	0.70	1.10
$1/\tau_{\theta_2}$	0.55	0.50
τ	0	0.12
GAIN(K)	1.0	1.0
COST = 44.7		

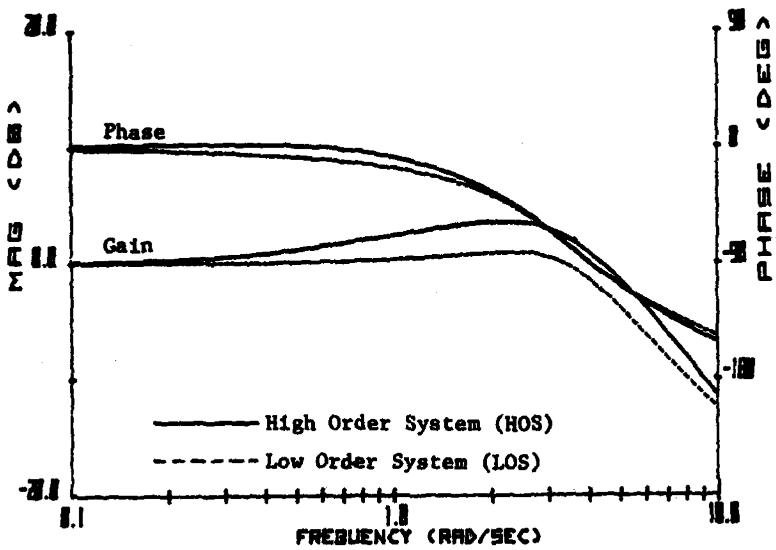


Control System
P1 (HOS)
$\frac{(20)(5)(2.5)}{(16.4)(6.7)(4.1)(.76)}$

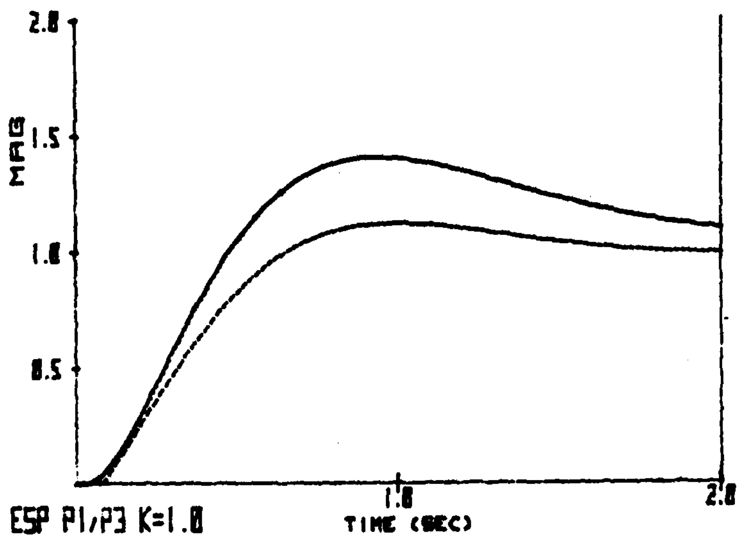
Figure D-11 Analytical Characteristics - Pitch Rate Response and Step Time History

PILOT COMMENTS

P1 - Teeniest bit of overcontrol but predictable. PR = 2.
P3 - Little overcontrol in flare. PR = 3.



Airframe	P1 HOS	P3 LOS
$\omega_{n_{SP}}$	3.21	3.50
ζ_{SP}	0.70	0.60
$1/\tau_{\theta_2}$	0.55	6.30
τ	0	0.07
GAIN(K)	1.0	1.0
COST = 73.8		

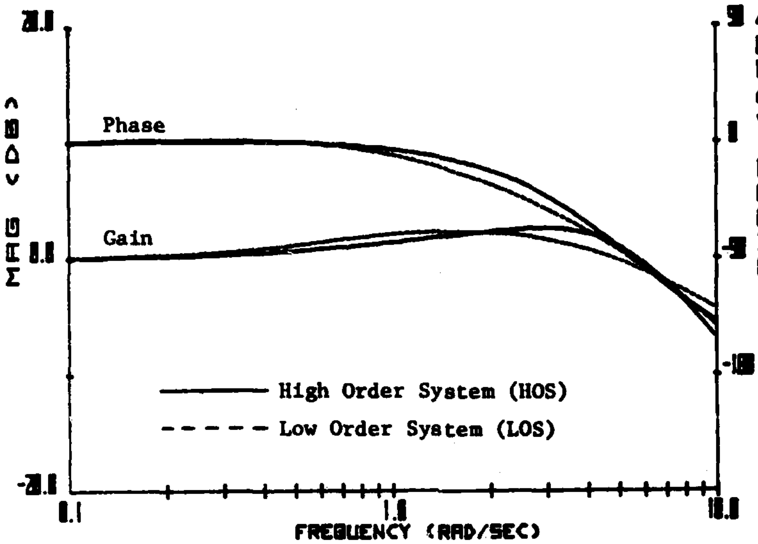


Control System
P1 (HOS)
$\frac{(20)(5)(2.5)}{(16.4)(6.7)(4.1)(.76)}$

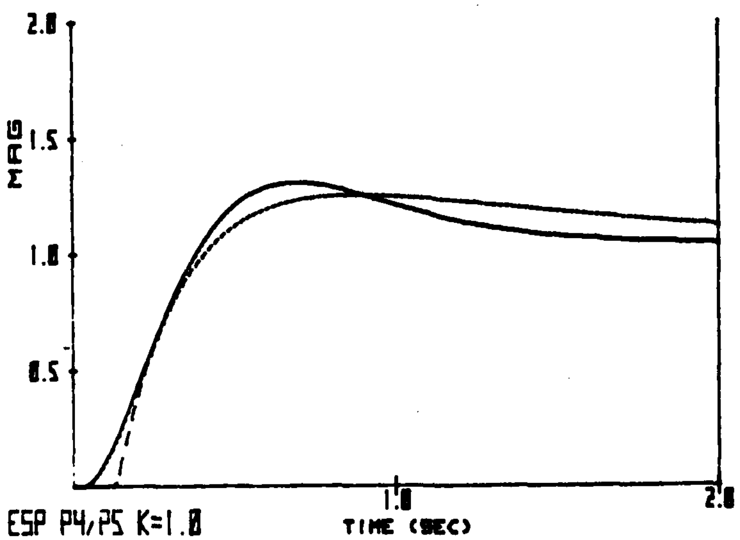
Figure D-12 Analytical Characteristics - Pitch Rate Response and Step Time History

PILOT COMMENTS

P4 - Nice little flare then noticed lag. Slight overcontrol. PR = 3.
P5 - Overcontrolled final response, quick response. PR = 6.



Airframe	P4 HOS	P5 LOS
$\omega_{n_{SP}}$	4.57	1.90
ζ_{SP}	0.81	1.40
$1/\tau_{\theta_2}$	0.55	0.55
τ	0	0.12
GAIN(K)	1.0	1.0
COST = 23.5		

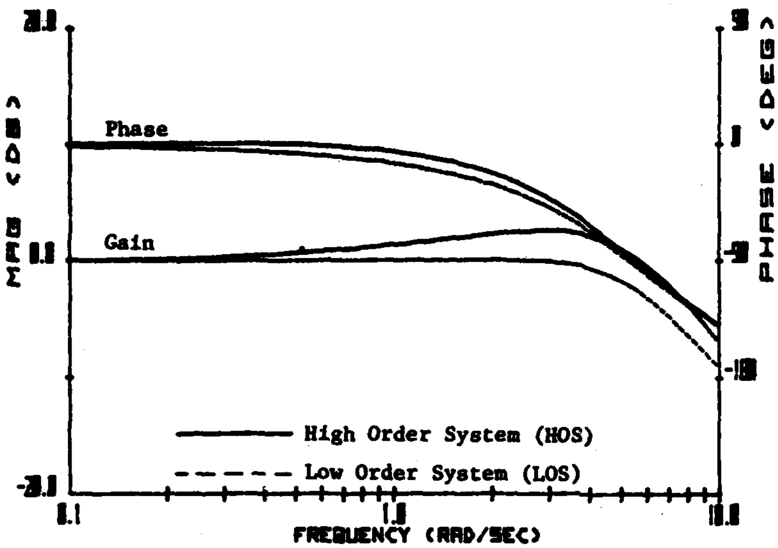


Control System
P4 (HOS)
$\frac{(2.5)(20)}{(12.3)(.64)(6.7)}$

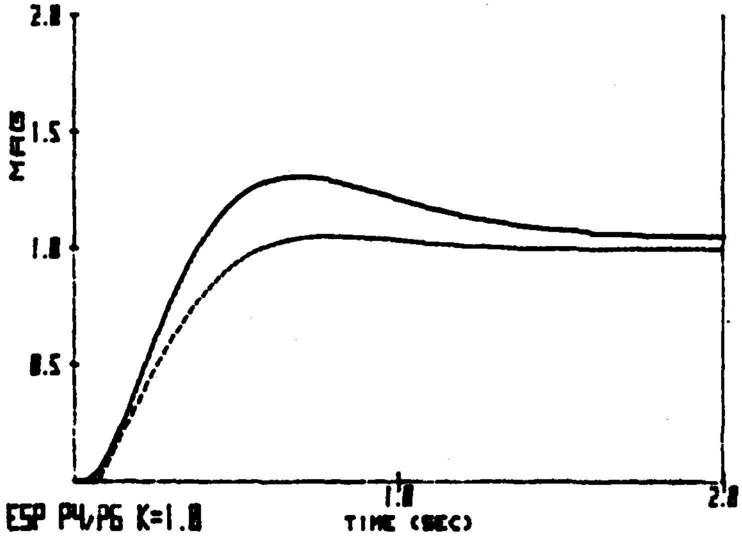
Figure D-13 Analytical Characteristics - Pitch Rate Response and Step Time History

PILOT COMMENTS

P4 - Nice little flare then noticed lag. Slight overcontrol. PR = 3.
P6 - Little bit of lag then bit of overcontrol. PR = 4.



Airframe		
	P4 HOS	P6 LOS
$\omega_{n_{SP}}$	4.57	5.30
ζ_{SP}	0.81	0.70
$1/\tau_{\theta_2}$	0.55	12.5
τ	0	0.06
GAIN(K)	1.0	1.0
COST = 74.0		

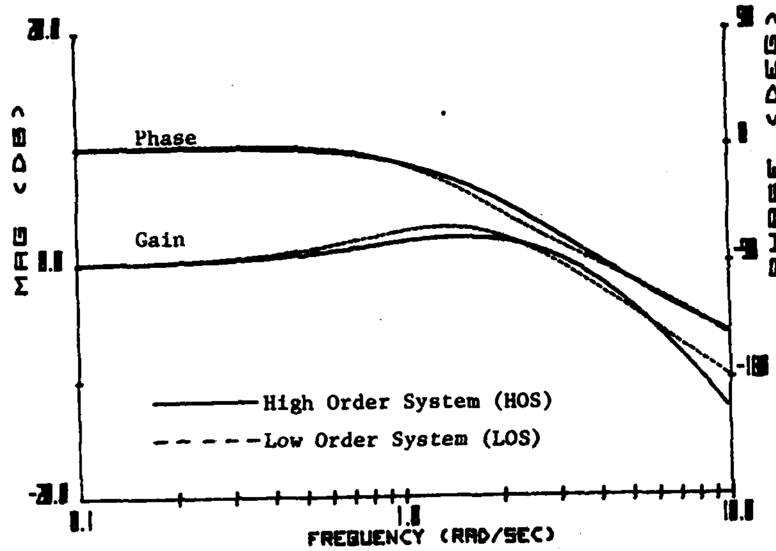


Control System
P4 (HOS)
$\frac{(2.5)(20)}{(12.3)(.64)(6.7)}$

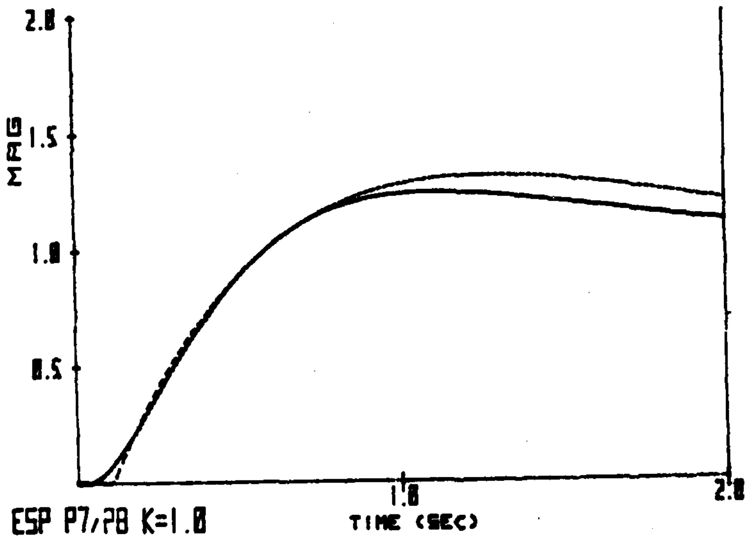
Figure D-14 Analytical Characteristics - Pitch Rate Response and Step Time History

PILOT COMMENTS

P7 - Slow initial response, overcontrolled final. PR = 4.
P8 - Bit of lag in initial response and overcontrol on final response, had to back out of loop a bit. PR = 5.



Airframe	P7 HOS	P8 LOS
$\omega_{n_{SP}}$	2.30	1.60
ζ_{SP}	1.10	0.80
$1/\tau_{\theta_2}$	0.80	0.80
τ	0	0.10
GAIN(K)	1.0	1.0
COST = 17.9		

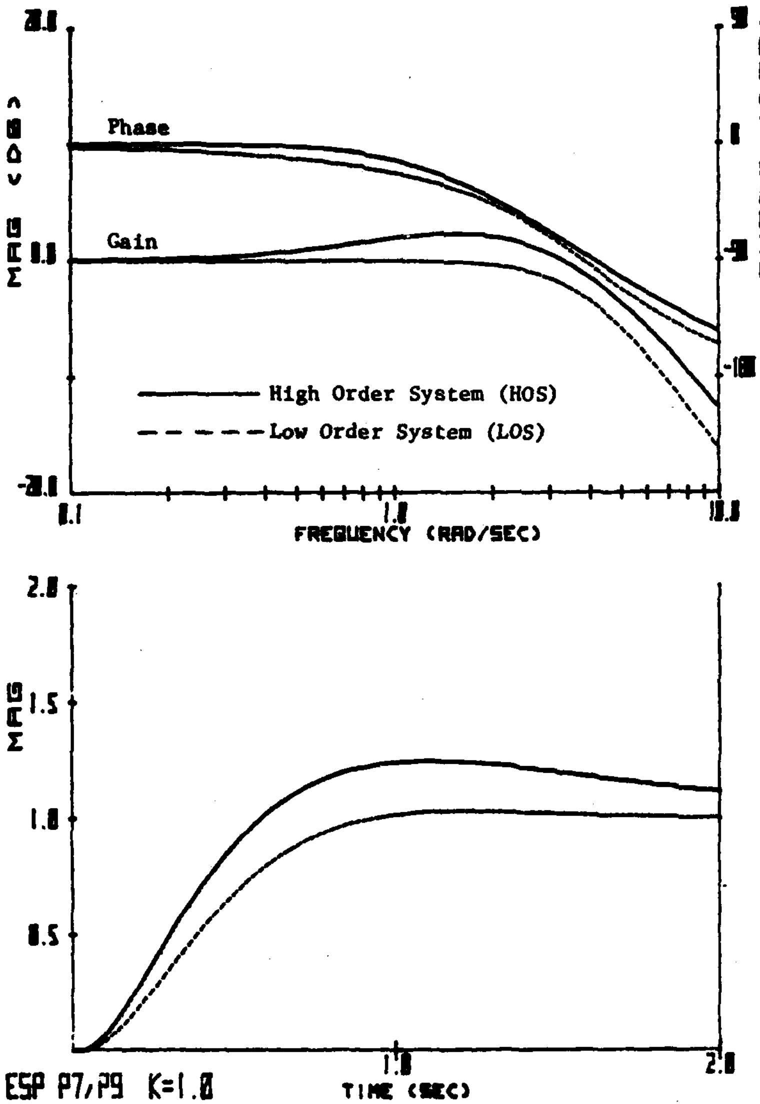


Control System
P7 (HOS)
$\frac{1}{(S + 4)}$

Figure D-15 Analytical Characteristics - Pitch Rate Response and Step Time History

PILOT COMMENTS

P7 - Slow initial response, overcontrolled final. PR = 4.
P9 - Overcontrolled a little in flare but a pretty good airplane. PR = 3.



Airframe	P7 HOS	P9 LOS
$\omega_{n_{SP}}$	2.30	4.00
ζ_{SP}	1.10	0.75
$1/\tau_{\theta_2}$	0.80	0
τ	0	0
GAIN(K)	1.0	1.0
COST = 85.2		

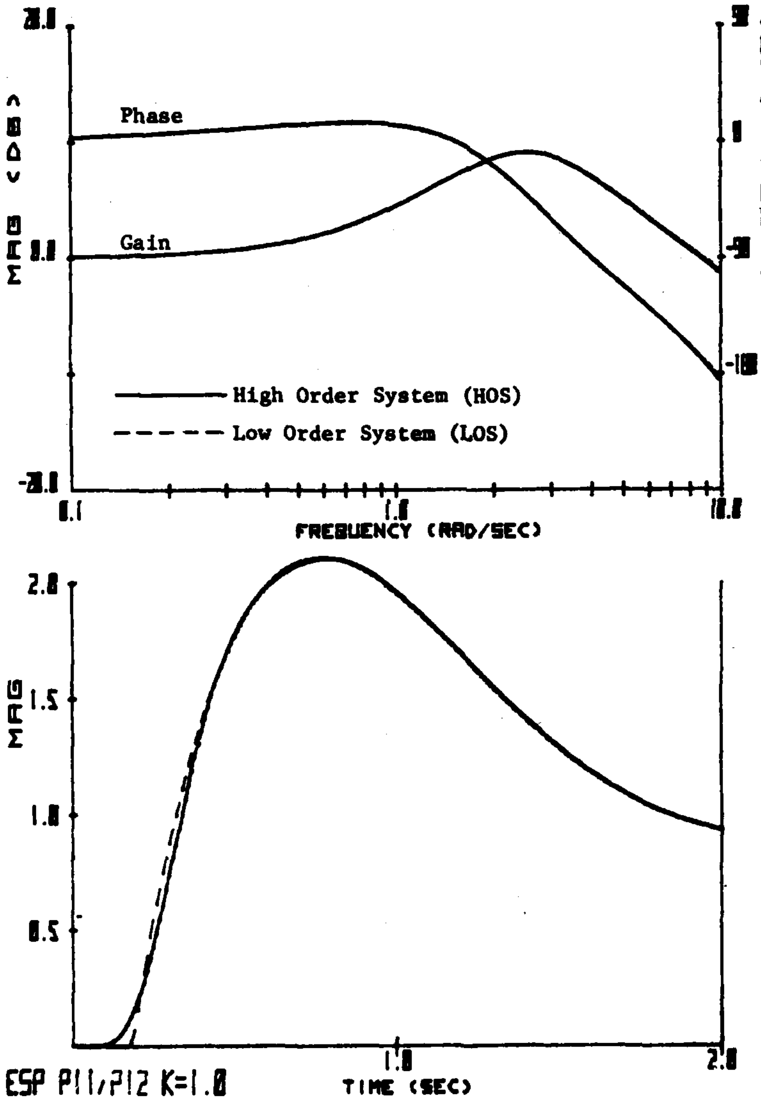
Control System
P7 (HOS)
$\frac{1}{(S + 4)}$

Figure D-16 Analytical Characteristics - Pitch Rate Response and Step Time History

PILOT COMMENTS

P11 - Tendency to overcontrol; got a small PIO, stayed in loop and was able to stay in control. PR = 6.

P12 - No problem until flare, had to back out of loop to land, fairly high frequency overcontrol. PR = 9.



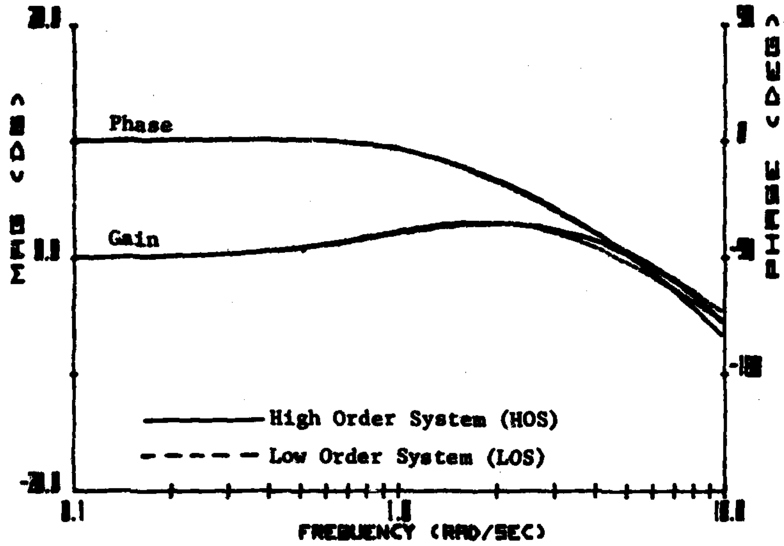
Airframe	P11 HOS	P12 LOS
$\omega_{n_{SP}}$	2.60	2.60
ζ_{SP}	0.60	0.60
$1/\tau_{\theta_2}$	0.80	0.80
τ	0	0.17
GAIN(K)	1.0	1.0
COST = 0.28		

Control System
P11 (HOS)
$\frac{1}{[.94;\ 16][.38;\ 16]}$

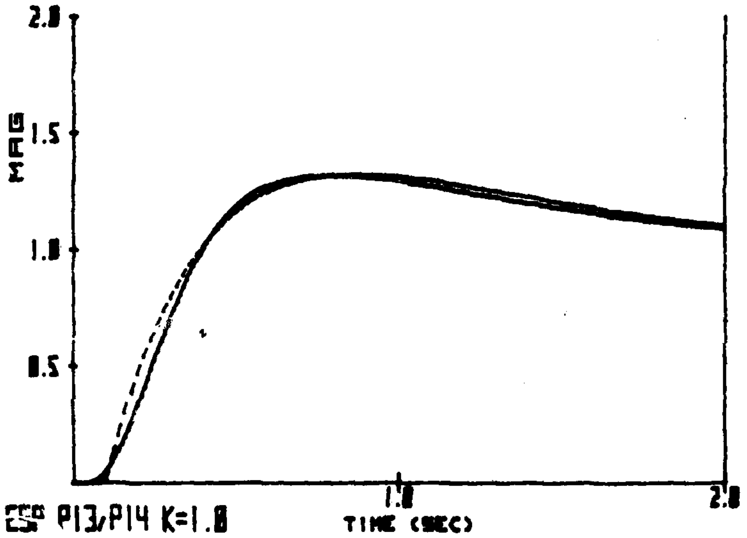
Figure D-17 Analytical Characteristics - Pitch Rate Response and Step Time History

PILOT COMMENTS

P13 - Overcontrolled nose slightly in flare, pretty good airplane. PR = 3.
P14 - Problem in the final flare; very nice airplane until one tried to quickly move attitude. PR = 5.



Airframe	P13 HOS	P14 LOS
$\omega_{n_{SP}}$	2.30	2.10
ζ_{SP}	1.10	1.00
$1/\tau_{\theta_2}$	0.80	0.80
τ	0	0.09
GAIN(K)	1.0	1.0
COST = 11.9		



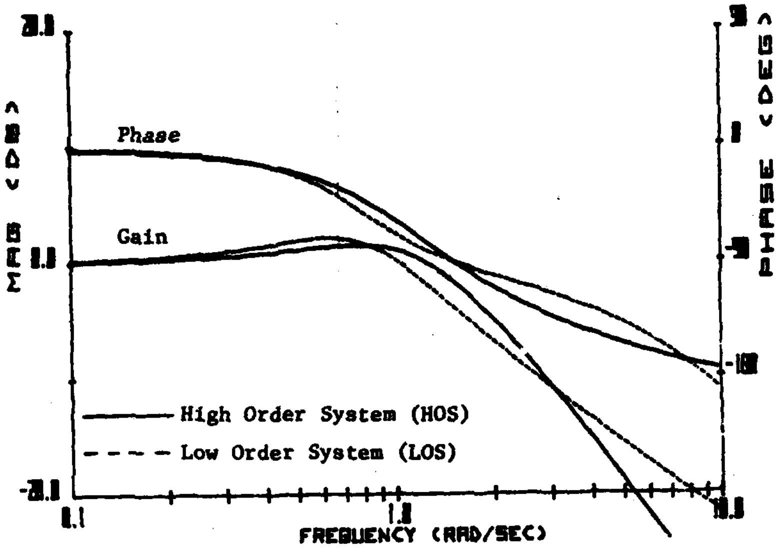
Control System
P13 (HOS)
$\frac{1}{[.7;\ 12]}$

Figure D-18 Analytical Characteristics - Pitch Rate Response and Step Time History

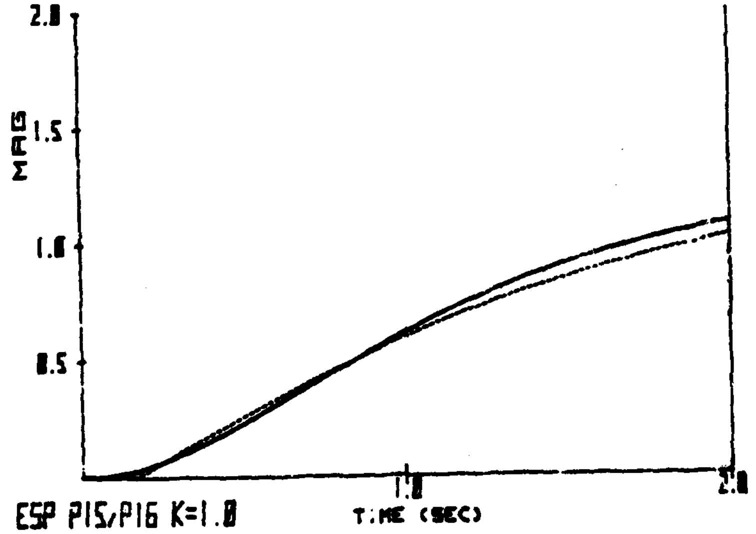
PILOT COMMENTS

P15 - Initial response very slow, over control final response, aircraft lacked precision. PR = 8.

P16 - Initial response very slow, final response also slow, work load very high. PR = 8.



Airframe	P15 HOS	P16 LOS
$\omega_{n_{SP}}$	1.10	0.80
ζ_{SP}	0.70	0.60
$1/T_{\theta_2}$	0.80	0.80
τ	0	0.16
GAIN(K)	1.0	1.0
COST = 194.3		



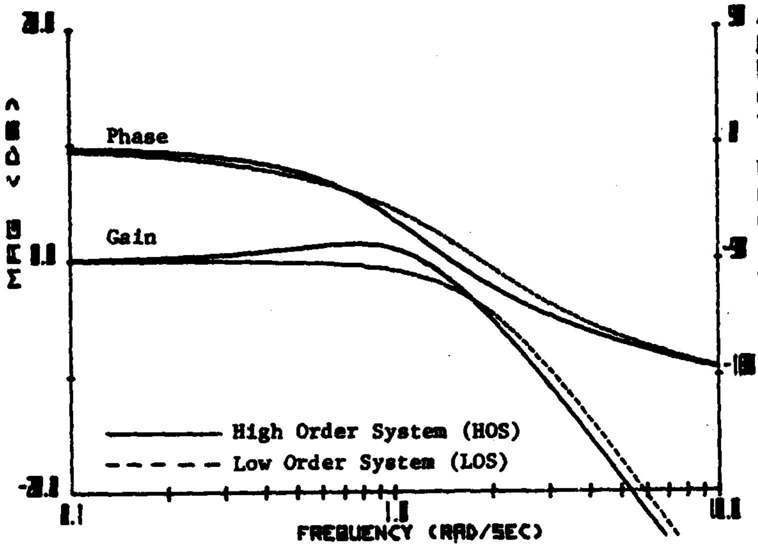
Control System
P15 (HOS)
$\frac{1}{(S + 2.0)}$

Figure D-19 Analytical Characteristics - Pitch Rate Response and Step Time History

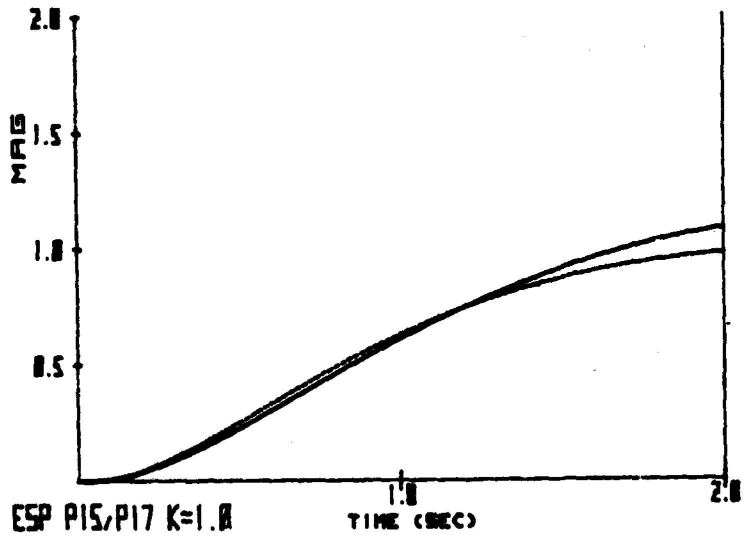
PILOT COMMENTS

P15 - Initial response very slow, overcontrol final response, aircraft lacked precision. PR = 8.

P17 - Pitch attitude very slow, final response unpredictable. PR = 9.



Airframe		
	P15 HOS	P17 LOS
$\omega_{n_{SP}}$	1.10	1.90
ζ_{SP}	0.70	0.80
$1/\tau_{\theta_2}$	0.80	∞
τ	0	0
GAIN(K)	1.0	1.0
COST = 49.4		

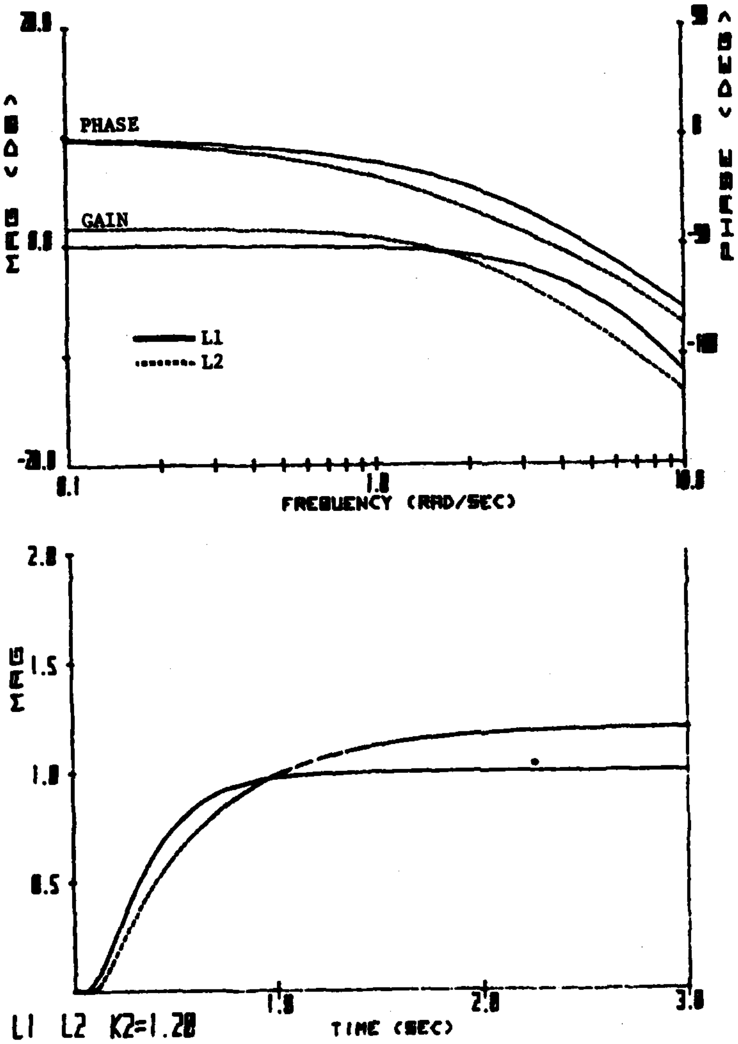


Control System
P15 (HOS)
$\frac{1}{(S + 2.0)}$

Figure D-20 Analytical Characteristics - Pitch Rate Response and Step Time History

PILOT COMMENTS

L1 - Little too sensitive initially then sluggish for large turns. PR = 4
L2 - Similar to L1. Forces a little bit heavier. PR = 3.



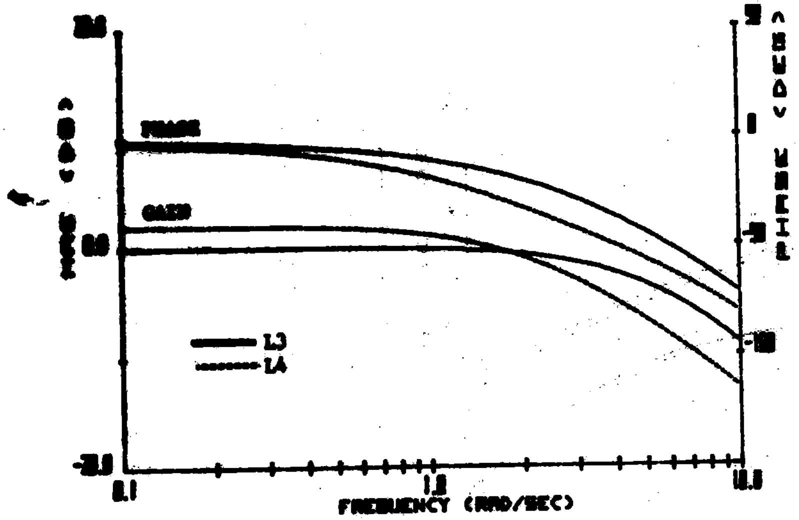
Airframe	L1	L2
τ_R (Nominal)	(HOS-3)	.45
τ_R (Correct)	-	.5
λ_D	-	20
τ	0	.07
P_{ss}	5	6
GAIN(K)	1.0	1.2
COST = 109.4		

Control System
L1 (HOS)
$\frac{(22)}{(38)\ (23)\ (5.6)\ (5)}$

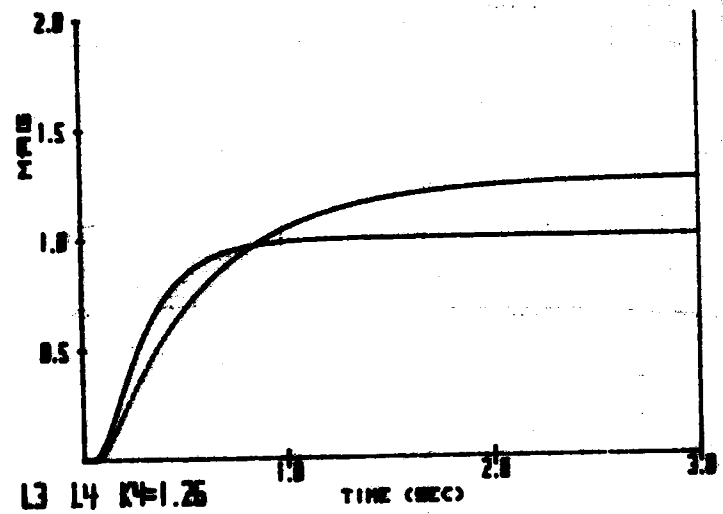
FIGURE D-21 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L3 - Strange force feel in roll (unpleasant roll response). PR = 4
L4 - Little too sensitive in roll. PR = 4



Airframe		
	L3	L4
τ_R (Nominal)	(HOS-4)	.45
τ_R (Correct)	-	.5
λ_D	-	20
τ	0	.05
P_{ss}	5	10
GAIN(K)	1.0	1.26
COST = 188.4		

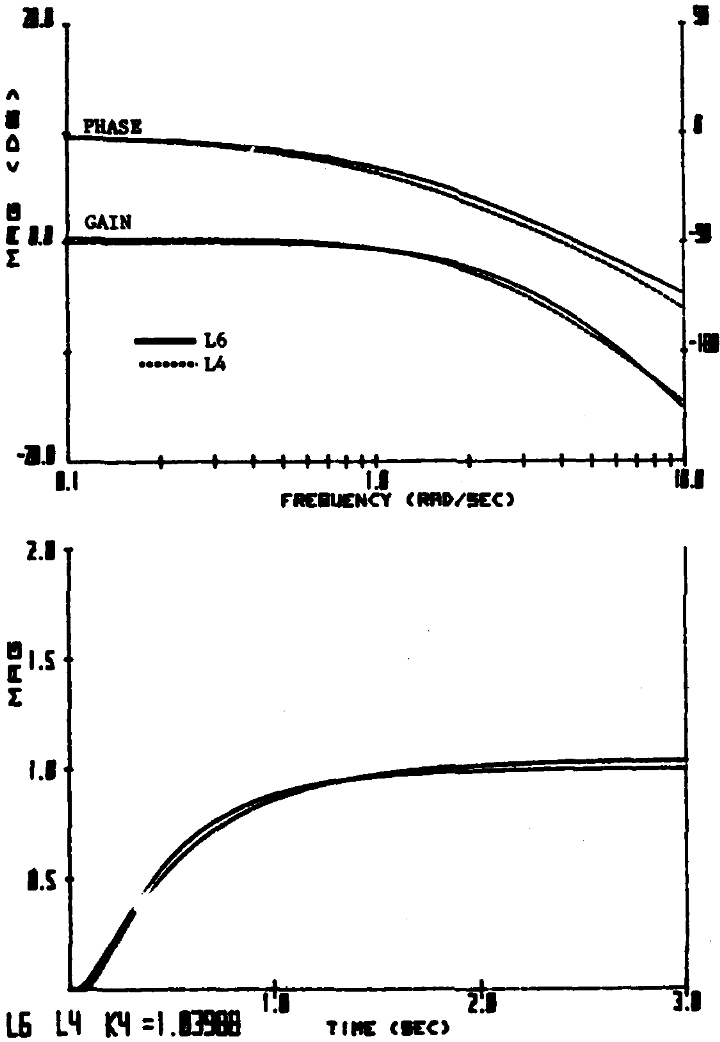


Control System
L3 (HOS)
$\frac{(22)}{(30)\ (24)\ (9.2)\ (5)}$

FIGURE B-22 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L6 - Everything was good. PR = 2
L4 - Little too sensitive in roll. PR = 4



Airframe		
	L6	L4
τ_R (Nominal)	.40	.45
τ_R (Correct)	.4	.5
λ_D	10	20
τ	0	.05
P_{ss}	5	10
GAIN(K)	1.0	1.0399
COST = 13.73		

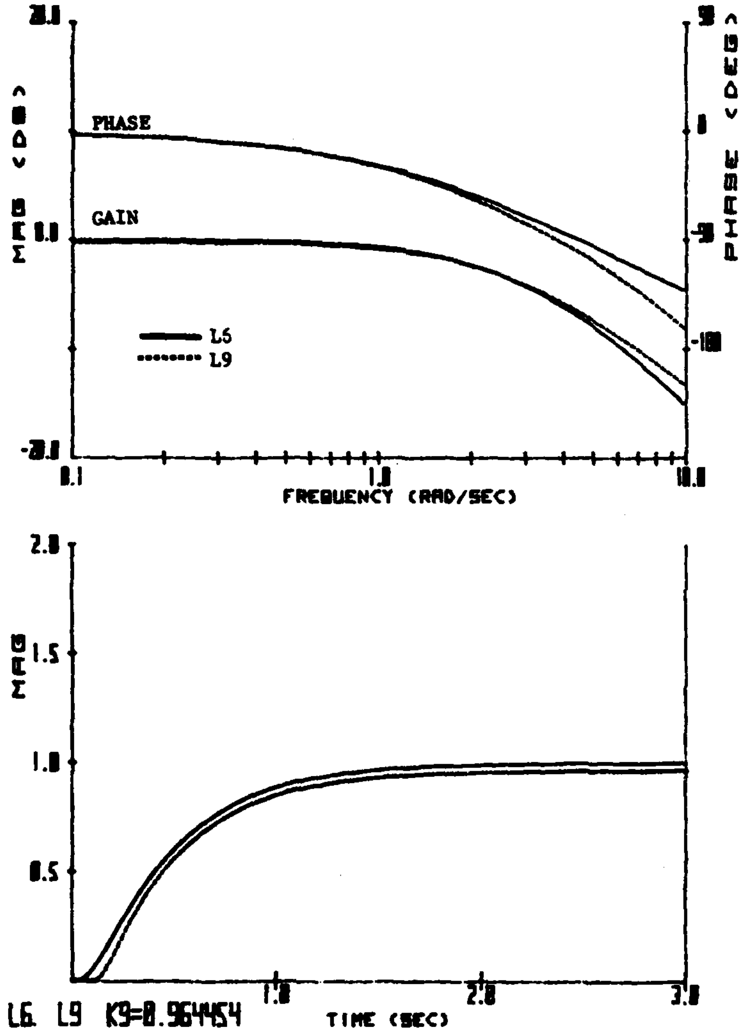
Control System
L6 (HOS)
$\frac{0}{(S + 4)}$

FIGURE D-23 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L6 - Everything was good. PR = 2

L9 - Crisp, good predictability, little lag notices in initial response. PR = 2



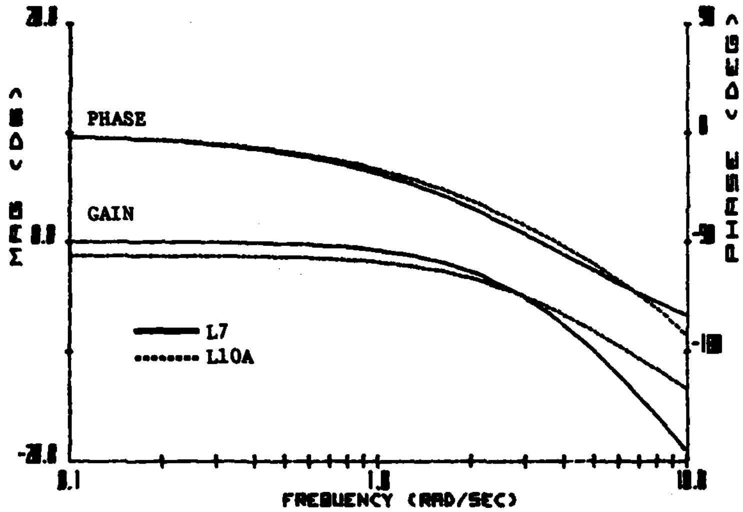
Airframe		
	L6	L9
τ_R (Nominal)	.40	.40
τ_R (Correct)	.4	.4
λ_D	10	20
τ	0	.09
P_{ss}	5	5
GAIN(K)	1.0	0.9645
COST = 46.4		

Control System
L6 (HOS)
$\frac{0}{(S + 4)}$

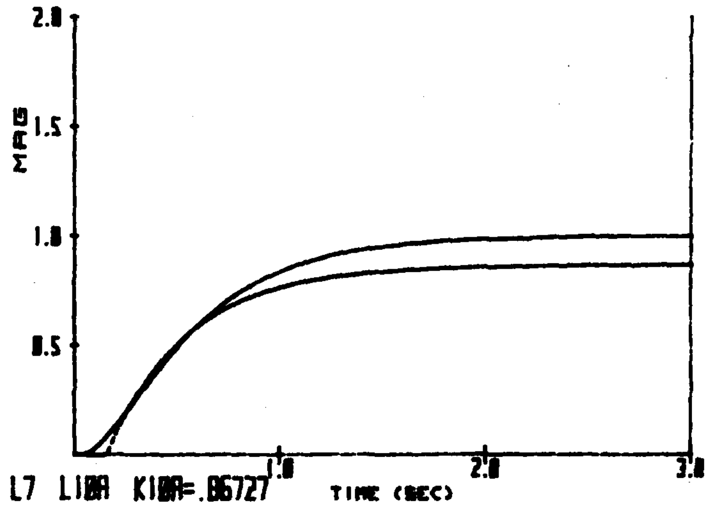
FIGURE D-24 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L7 - Desired response required overdrive, but seemed to stop crisply. PR = 3
L10A - Satisfactory, little P.I.O on second landing. PR = 3.5



Airframe		
	L7	L10A
τ_R (Nominal)	.40	.40
τ_R (Correct)	.4	.4
λ_D	5	-
τ	0	.14
P_{ss}	5	3
GAIN(K)	1.0	0.8673
COST = 87		

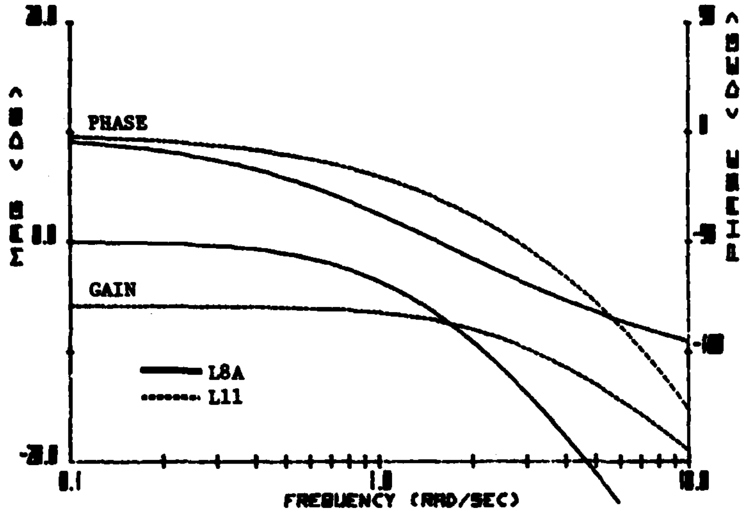


Control System
L7 (HOS)
$\frac{0}{(S + 4)}$

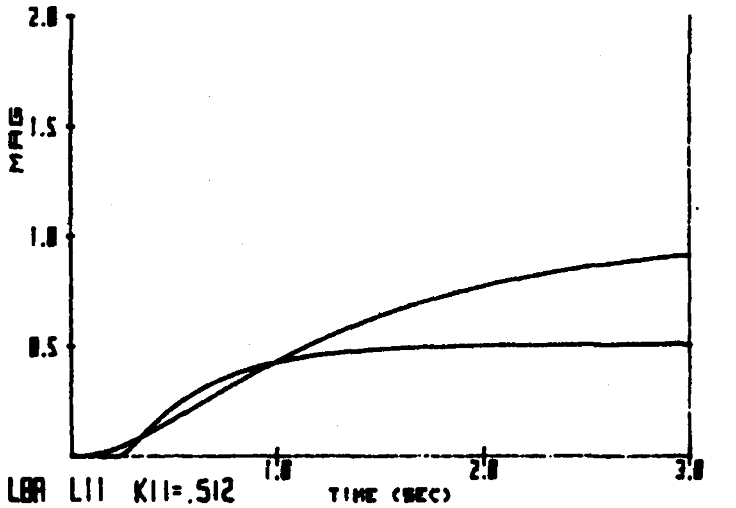
FIGURE D-25 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L8A - Slow bank angle oscillations in turn. PR = 6
L11 - Slight tendency to over control, no P.I.O. PR = 3



Airframe	L8A	L11
τ_R (Nominal)	.40	.40
τ_R (Correct)	.4	.4
λ_D	1	20
τ	-	.20
P_{ss}	7	4
GAIN(K)	1.0	0.512
COST = 1008		

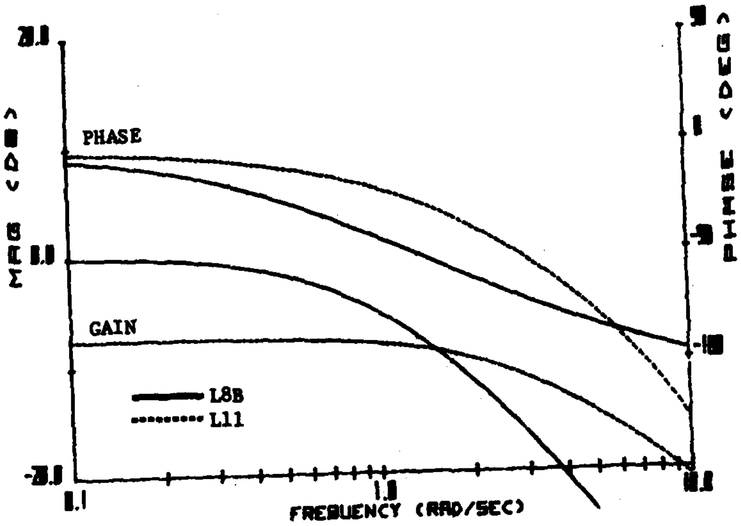


Control System
L8A (HOS)
$\frac{0}{(S + 4)}$

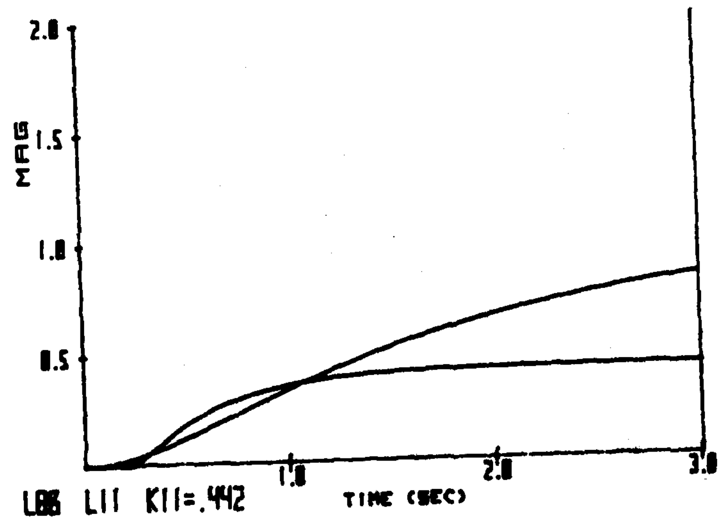
FIGURE D-26 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L8B - Easy to overcontrol. Dangerous aircraft in close in roll. PR = 9
L11 - Slight tendency to overcontrol, no P.I.O. PR = 3



Airframe		
	L8B	L11
τ_R (Nominal)	.40	.40
τ_R (Correct)	.4	.4
λ_D	.7	20
τ	-	.20
P_{ss}	5	4
(GAIN(K)	1.0	0.442
COST = 1397		

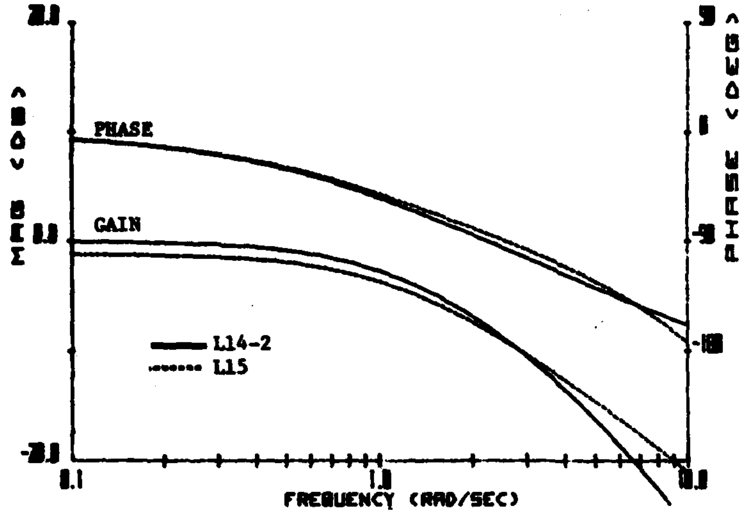


Control System
L8B (HOS)
$\frac{0}{(S + 4)}$

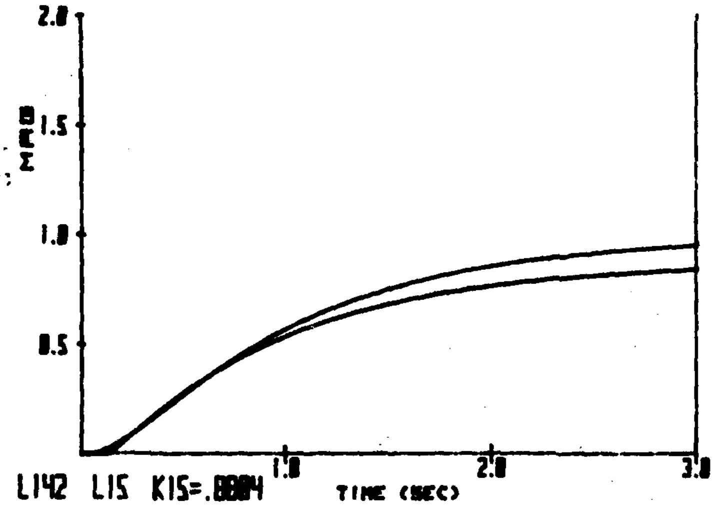
FIGURE D-27 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L14-2 - Sidestep was difficult, roll control not acceptable. PR = 7
L15 - Wanted a more responsive roll control. PR = 4



Airframe		
	L14-2	L15
τ_R (Nominal)	.90	.90
τ_R (Correct)	.9	.9
λ_D	5	20
τ	-	.09
P_{ss}	6	9
GAIN(K)	1.0	0.8804
COST = 68		

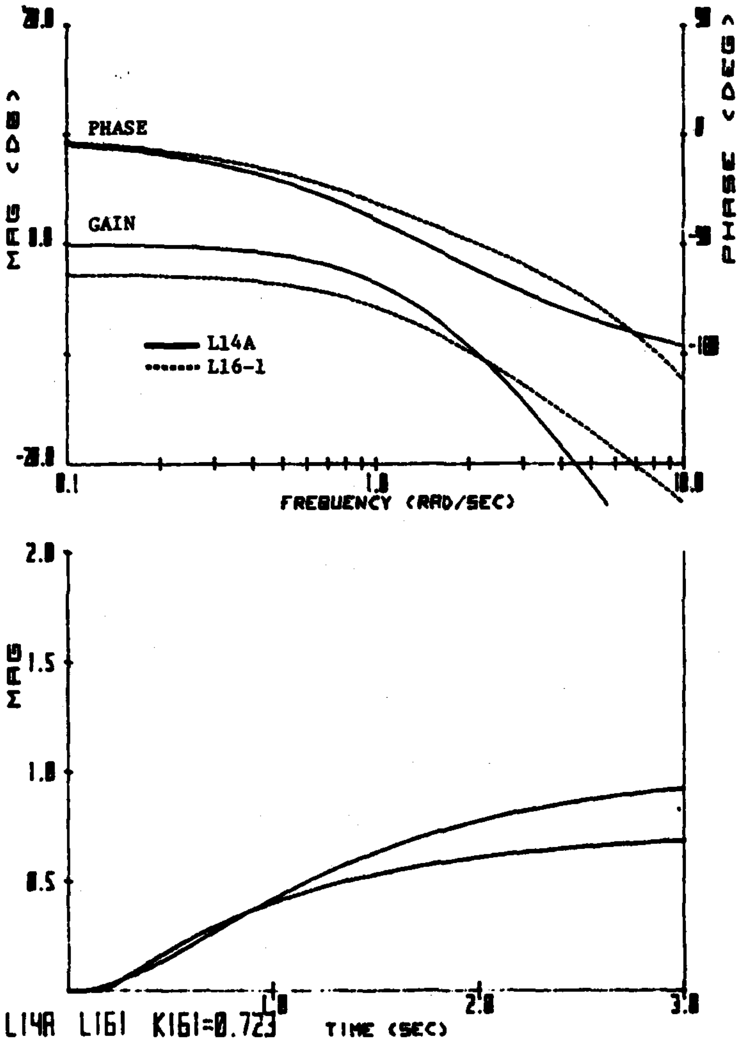


Control System
L14-2 (HOS)
$\frac{0}{(S + 4)}$

FIGURE D-28 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L14A - Bank angle control not satisfactory, slow response. PR = 7
L16-1 - Slightly heavy in roll response. PR = 3



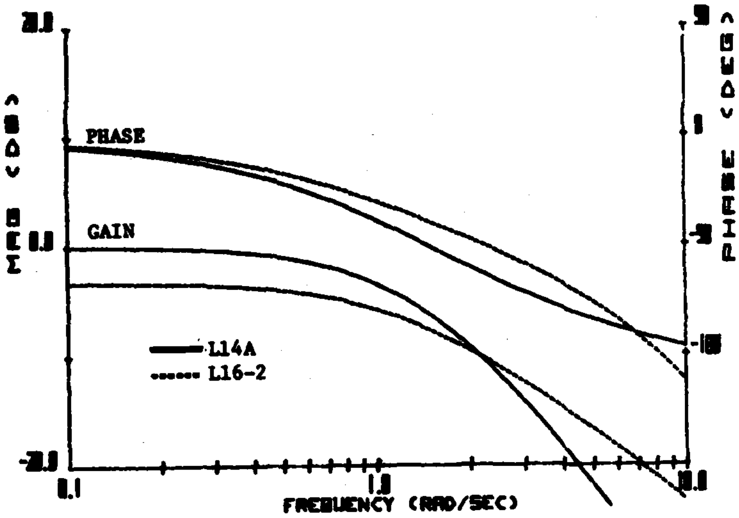
Airframe		
	L14A	L16-1
τ_R (Nominal)	.90	.90
τ_R (Correct)	.9	.9
λ_D	2	20
τ	0	.14
P_{ss}	7	6
GAIN(K)	1.0	0.723
COST = 410.3		

Control System
L14A (HOS)
$\frac{0}{(S + 4)}$

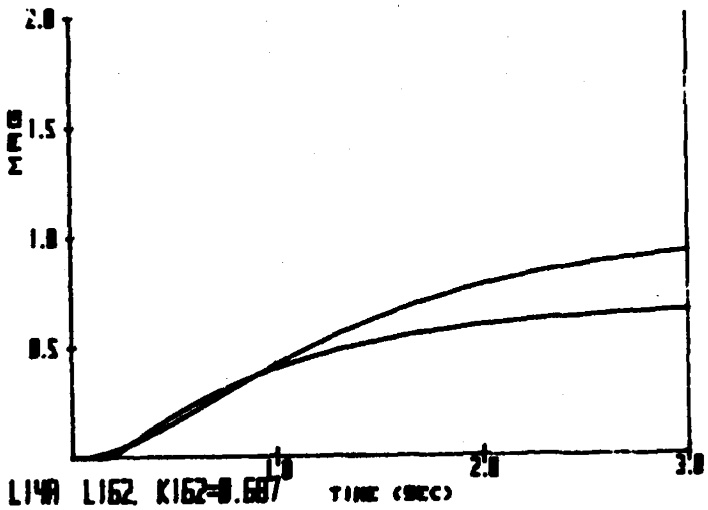
FIGURE D-29 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L14A - Bank angle control not satisfactory, slow response. PR = 7
L16-2 - Quick to respond but not predictable. PR = 4



Airframe		
	L14A	L16-2
τ_R (Nominal)	~~.90~~	.90
τ_R (Correct)	.9	.9
λ_D	2	20
τ	0	.14
P_{ss}	7	6
GAIN(K)	1.0	0.687
COST = 423.		

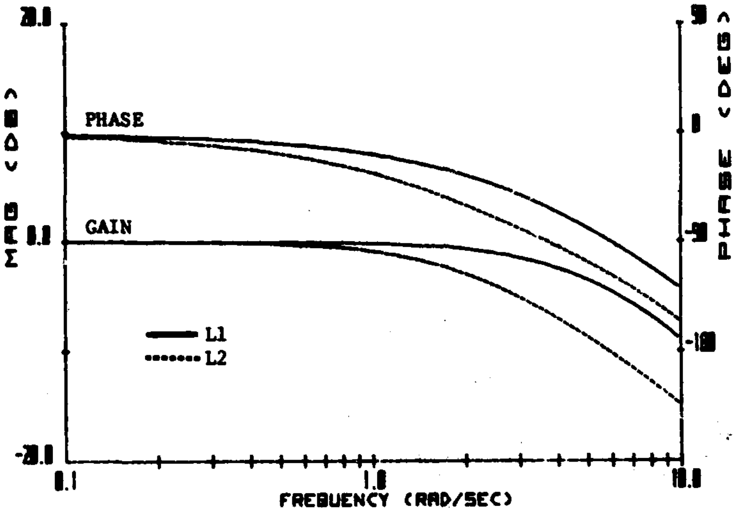


Control System
L14A (HOS)
$\frac{0}{(S + 4)}$

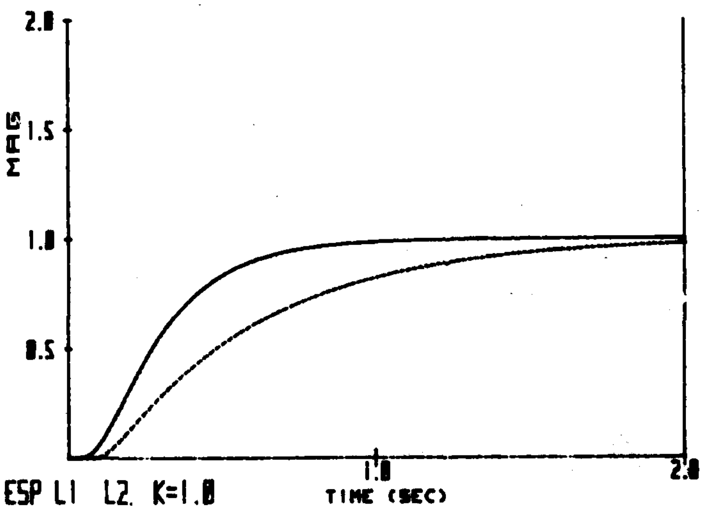
FIGURE D-30 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L1 - Little too sensitive initially then sluggish for large turns. PR = 4
L2 - Similar to L1. Forces a little bit heavier. PR = 3



Airframe		
	L1	L2
τ_R (Nominal)	(HOS-3)	.45
τ_R (Correct)	-	.5
λ_D	-	20
τ	0	.07
P_{ss}	5	6
GAIN(K)	(1.0)	(1.0)
COST = 158		

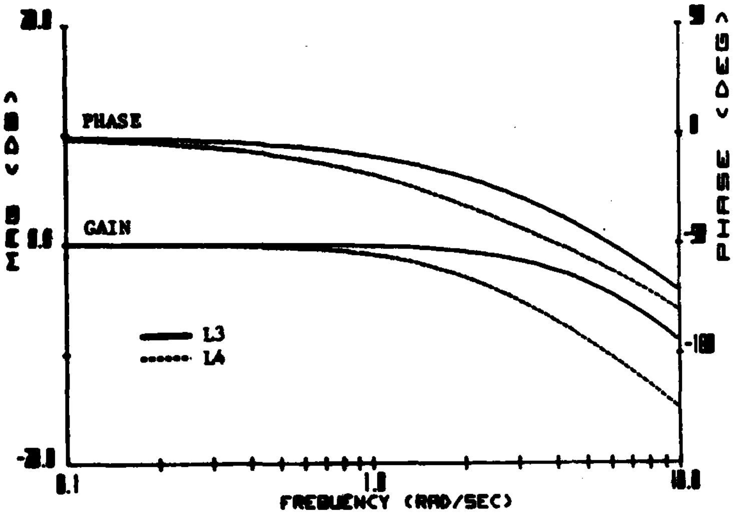


Control System
L1 (HOS)
$\frac{(22)}{(38)\ (23)\ (5.6)\ (5)}$

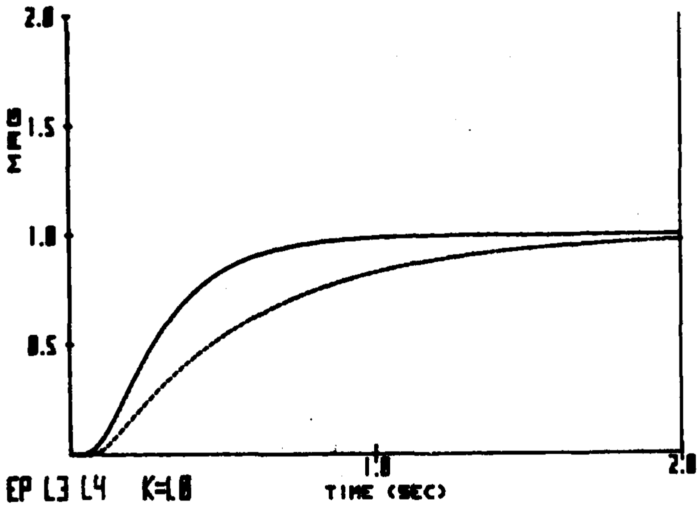
FIGURE D-31 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L3 - Strange force feel in roll (unpleasant roll response). PR = 4
L4 - Little too sensitive in roll. PR = 4



Airframe		
	L3	L4
τ_R (Nominal)	(HOS-4)	.45
τ_R (Correct)	-	.5
λ_D	-	20
τ	0	.05
P_{ss}	5	10
GAIN(K)	1.0	1.0
COST = 268.6		

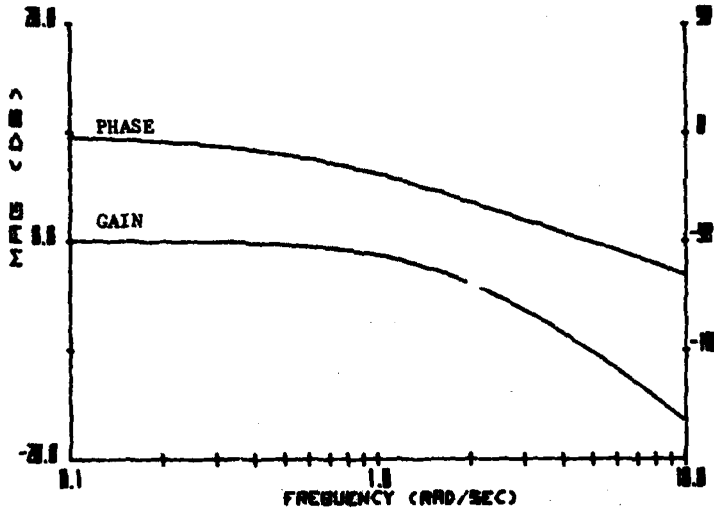


Control System
L3 (HOS)
$\frac{(22)}{(30)\ (24)\ (9.2)\ (5)}$

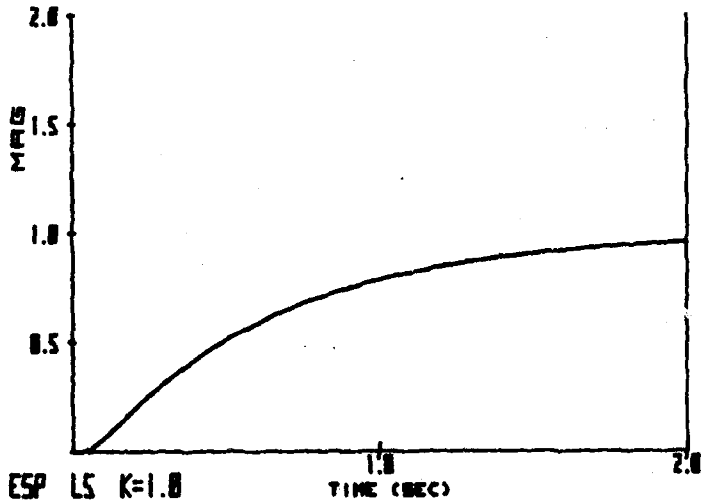
FIGURE D-32 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L5 - No problems, could fly it all day. PR = 2



Airframe	
	L5
τ_R (Nominal)	.4
τ_R (Correct)	.6
λ_D	20
τ	-
P_{ss}	4
GAIN(K)	1.0

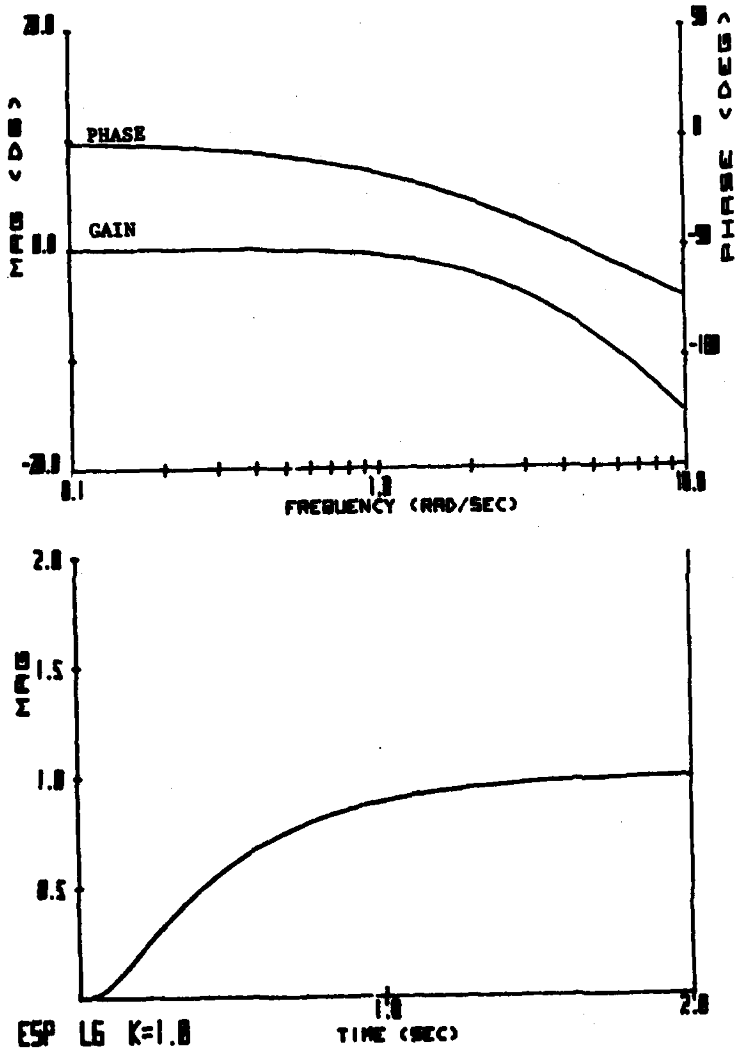


Control System
L5
$\frac{0}{(S + 4)}$

FIGURE D-33 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L6 - Everything was good.   PR = 2



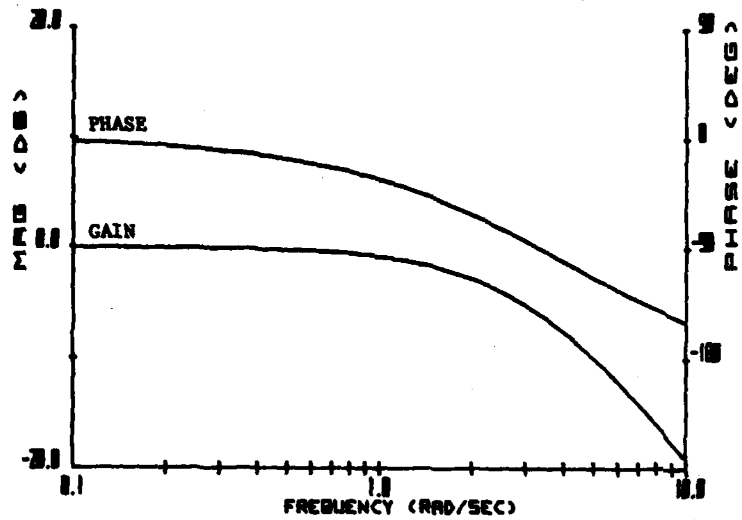
Airframe	
	L6
τ_R (Nominal)	.40
τ_R (Correct)	.4
λ_D	10
τ	-
P_{ss}	5
GAIN(K)	1.0

Control System
L6
$\frac{0}{(S+4)}$

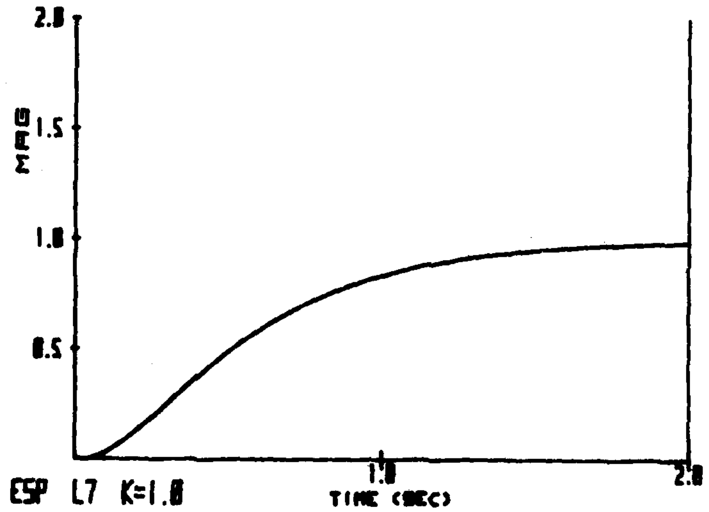
FIGURE D-34 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L7 - Desired response required overdrive, but seemed to stop crisply. PR = 3



Airframe	
	L7
τ_R (Nominal)	.40
τ_R (Correct)	.4
λ_D	5
τ	-
P_{ss}	5
GAIN(K)	1.0

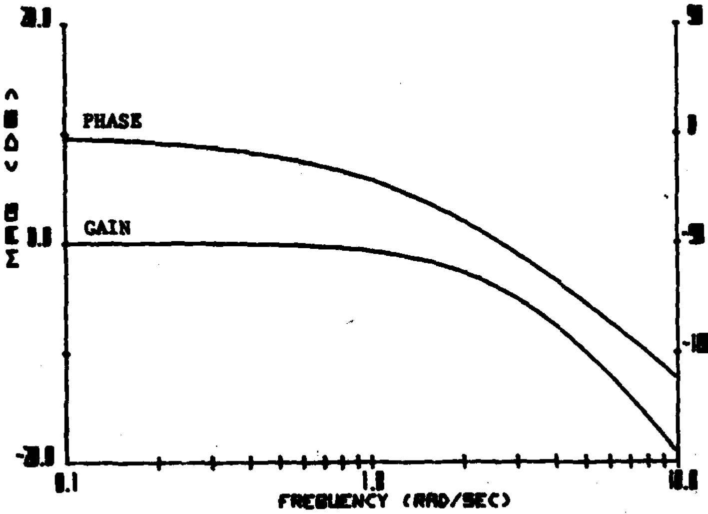


Control System
L7
$\frac{0}{(S+4)}$

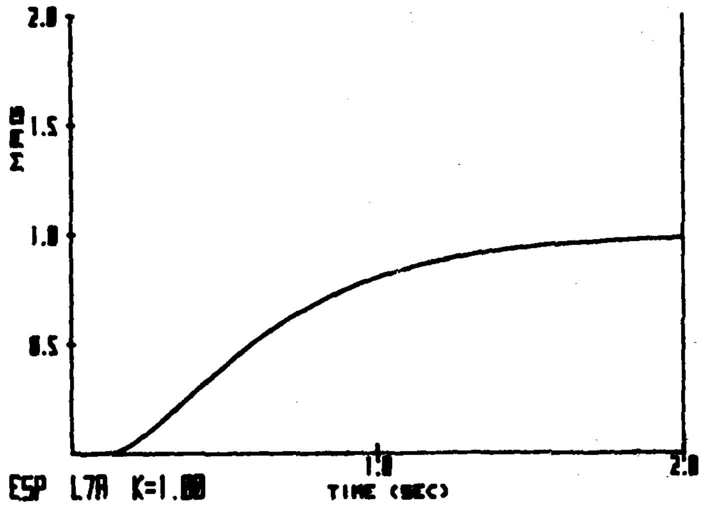
FIGURE D-35 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L7A - Okay, but must "push" airplane to get desired performance.   PR = 4



Airframe	
	L7A
τ_R (Nominal)	.40
τ_R (Correct)	.4
λ_D	5
τ	.09
P_{ss}	5
GAIN(K)	1.0

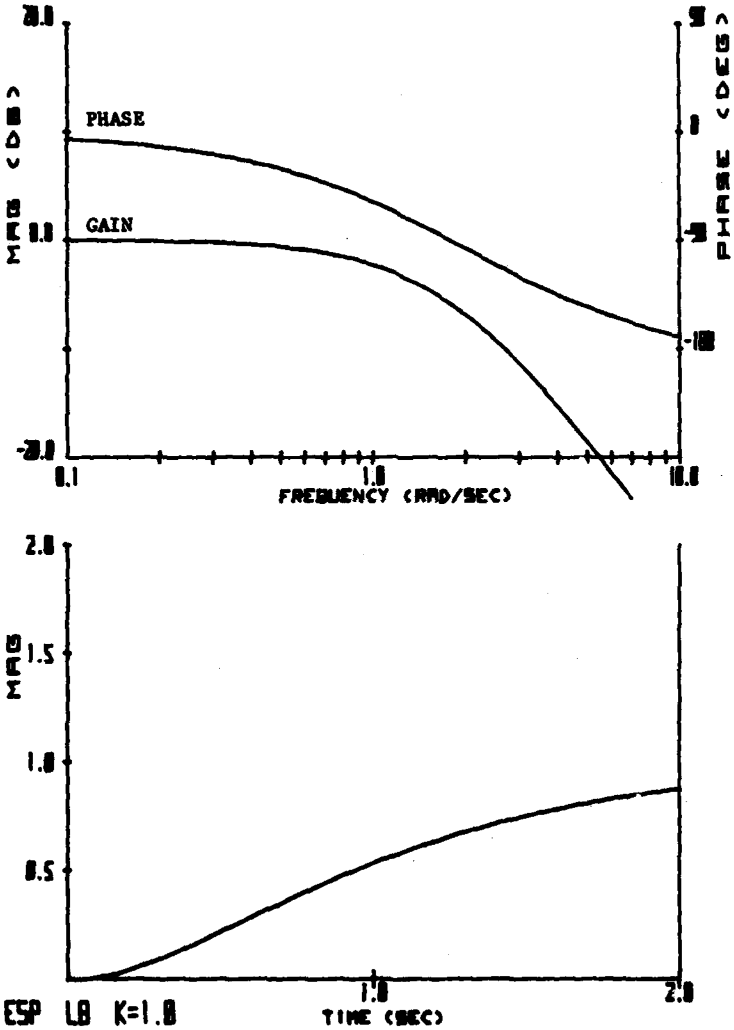


Control System
L7A
$\frac{1}{(S+4)}$

FIGURE D-36 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L8 - Had to be flown smoothly in roll. Overcontrolled. PR = 5



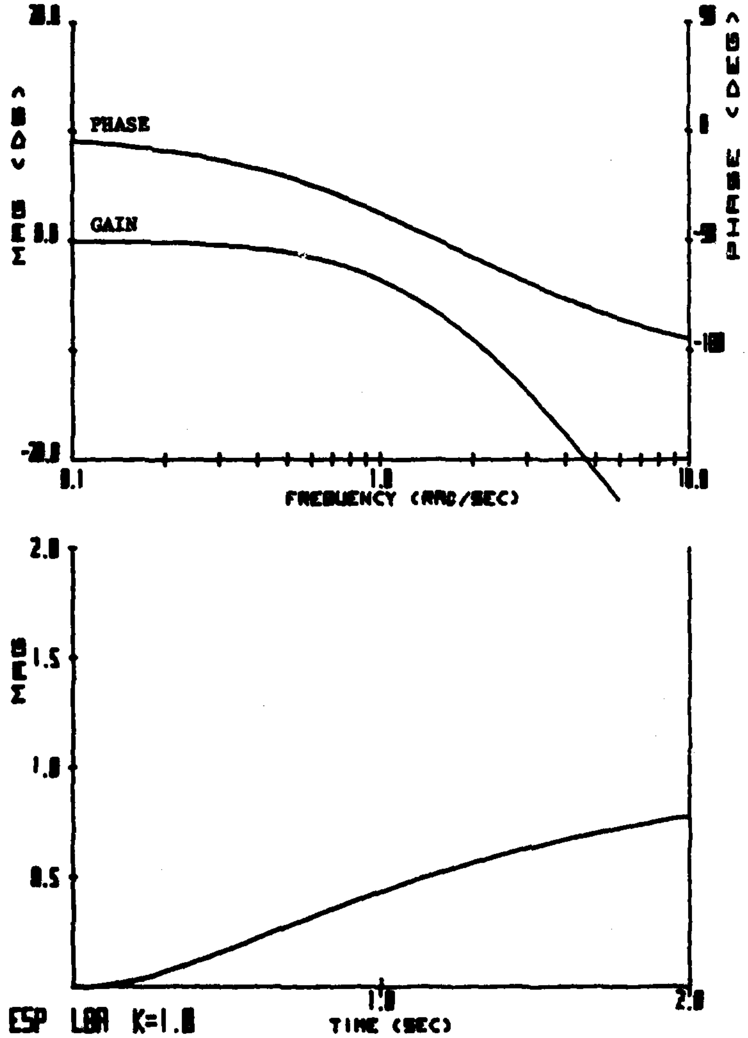
Airframe	
	L8
τ_R (NOMINAL)	.40
τ_R (CORRECT)	.6
λ_D	2
τ	-
P_{ss}	5
GAIN(K)	1.0

Control System
L8
$\frac{0}{(S + 4)}$

FIGURE D-37 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L8A - Slow bank angle oscillations in turn. PR = 6

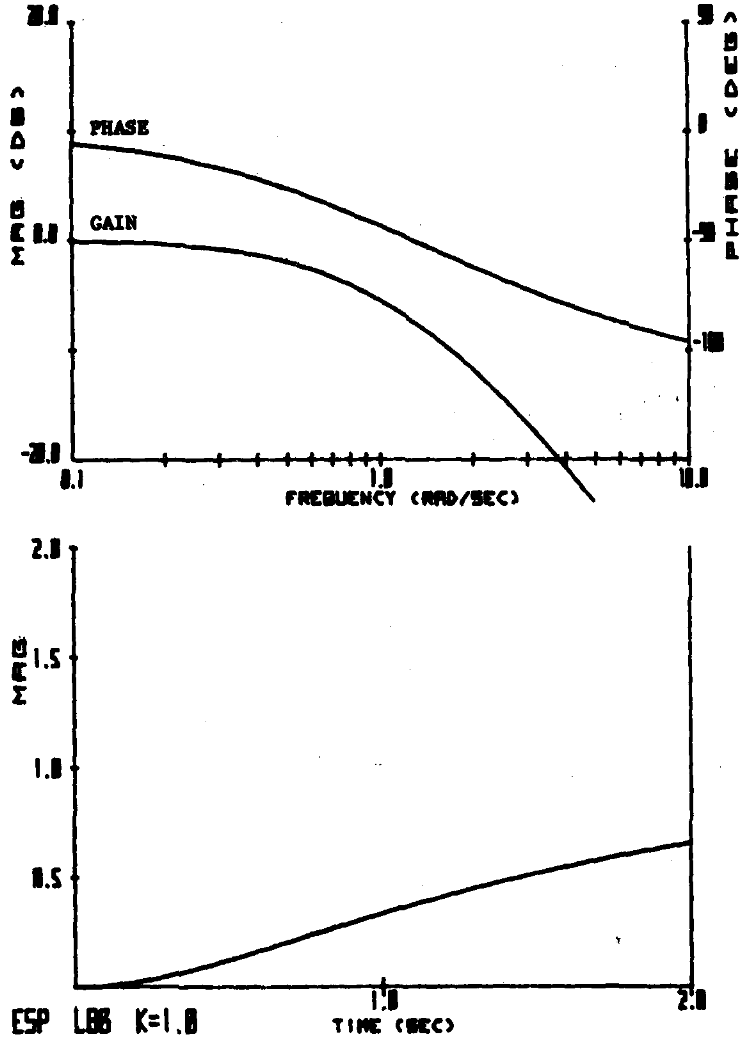


Airframe	L8A
τ_R (NOMINAL)	.40
τ_R (CORRECT)	.4
λ_D	1
τ	-
P_{ss}	7
GAIN(K)	1.0

Control System
L8A
$\frac{0}{(S + 4)}$

FIGURE D-38 Analytical Characteristics - Roll Rate Response and Step Time History

L8B - Easy to Overcontrol. Dangerous Aircraft in Close in Roll. PR = 9



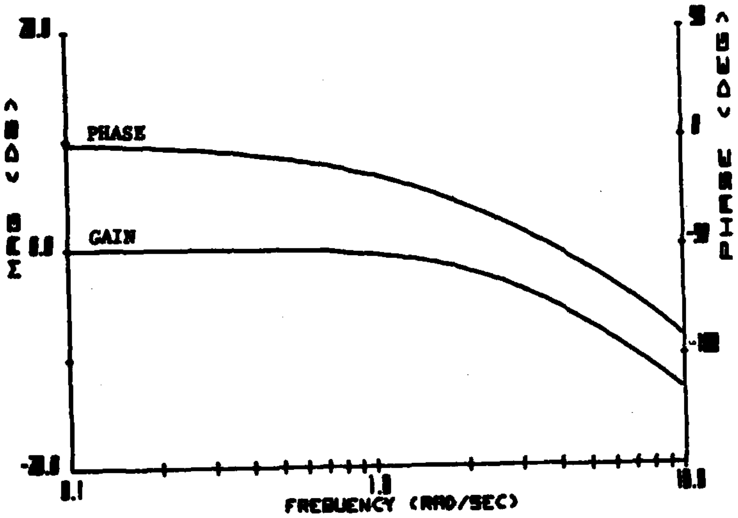
Airframe	
	L8B
τ_R (NOMINAL)	.40
τ_R (CORRECT)	.4
λ_D	0.7
τ	-
P_{ss}	5
GAIN(K)	1.0

Control System
L8B
$\frac{0}{(S + 4)}$

FIGURE D-39 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L9 - Crisp, good predictability, little lag noticed in initial response. PR = 2



Airframe	
	L9
τ_R (NOMINAL)	.40
τ_R (CORRECT)	.4
λ_D	20
τ	.09
P_{ss}	5
GAIN(K)	1.0

Control System
L9
$\frac{1}{(S + 4)}$

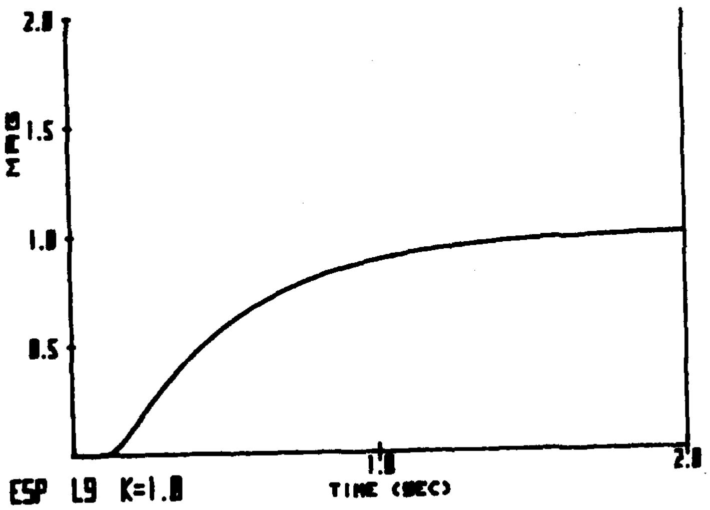
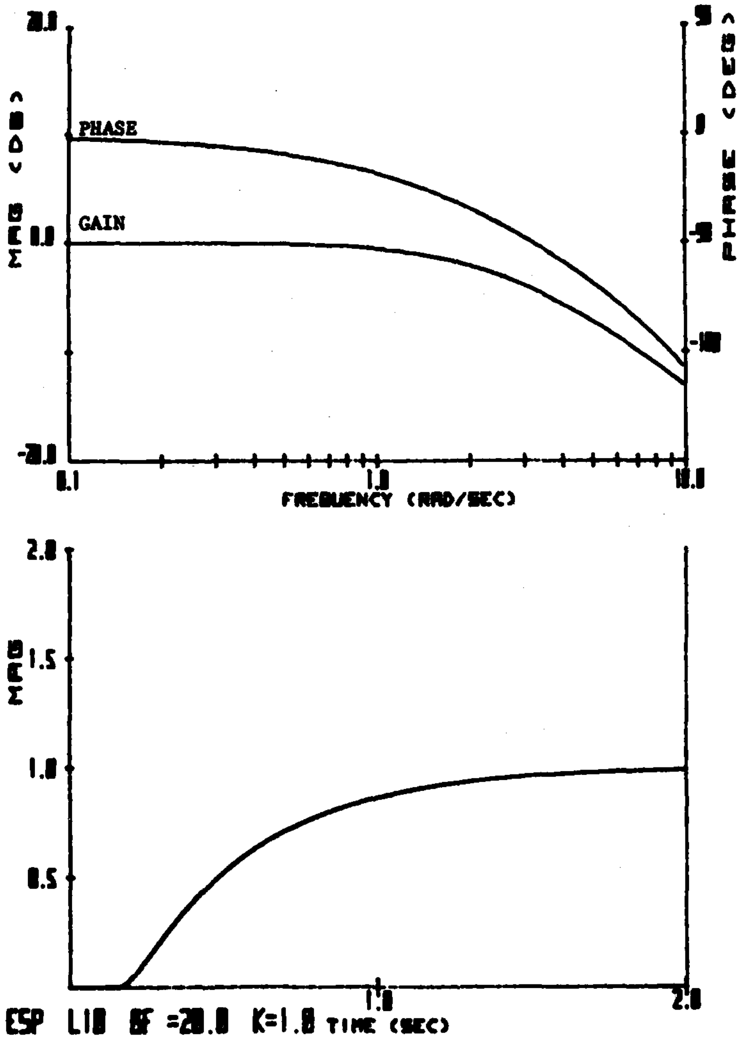


FIGURE D-40 Analytical Characteristics - Roll Rate Response and Step Time History

<u>PILOT COMMENTS</u>

L10 - Very gust responsive in roll.   PR = 5



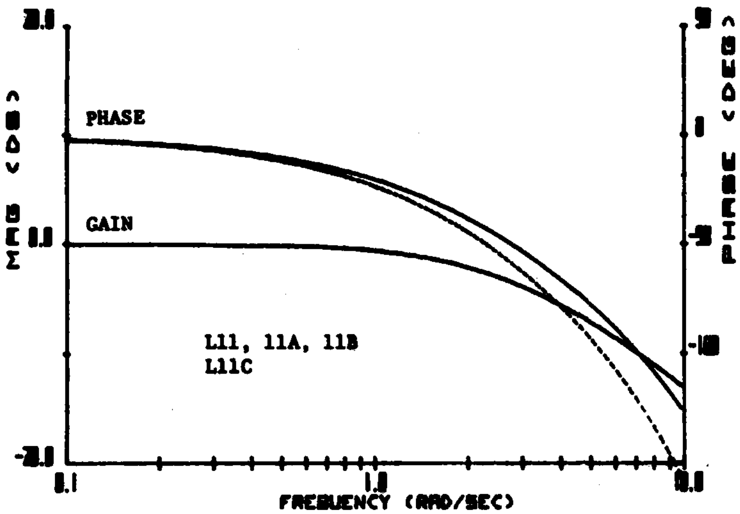
Airframe	
	L10
τ_R (NOMINAL)	.40
τ_R (CORRECT)	.4
λ_D	20
τ	.14
P_{ss}	5
GAIN(K)	1.0

Control System
L10
$\frac{1}{(S + 4)}$

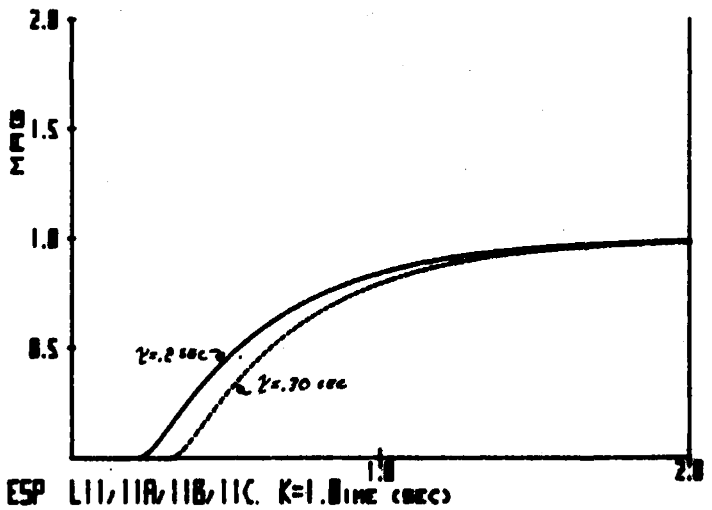
FIGURE D-41 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

F11	-	Slight tendency to overcontrol	PR = 3
L11A	-	Too sensitive in roll	PR = 6
L11B	-	Little on sluggish side	PR = 4
L11C	-	Roll control, slow then abrupt	PR = 9



Airframe				
	L11	L11A	L11B	L11C
τ_R (NOMINAL)	.40	.40	.40	.40
τ_R (CORRECT)	.4	.4	.4	.4
λ_D	20	20	20	20
τ	.20	.20	.20	.20
Pss	4	5	3	3
GAIN(K)	1.0	1.0	1.0	1.0

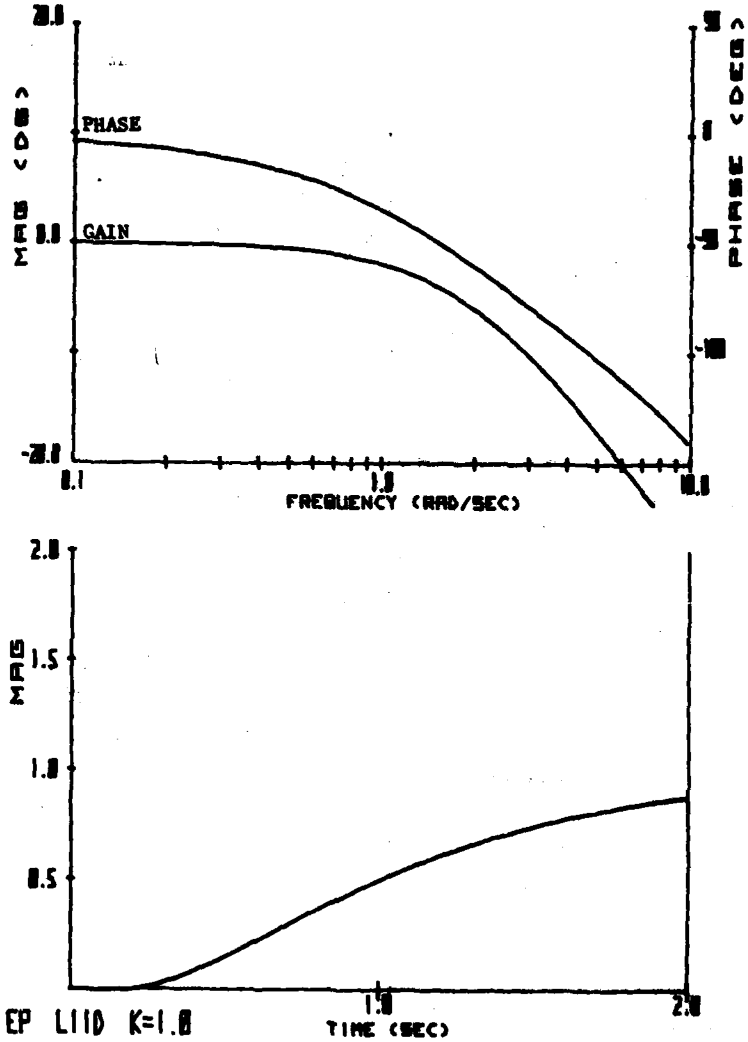


Control System
L11, 11A, 11B, 11C
$\frac{1}{(S + 4)}$

FIGURE D-42 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L11D - Roll control very poor, dangerous aircraft PR = 10



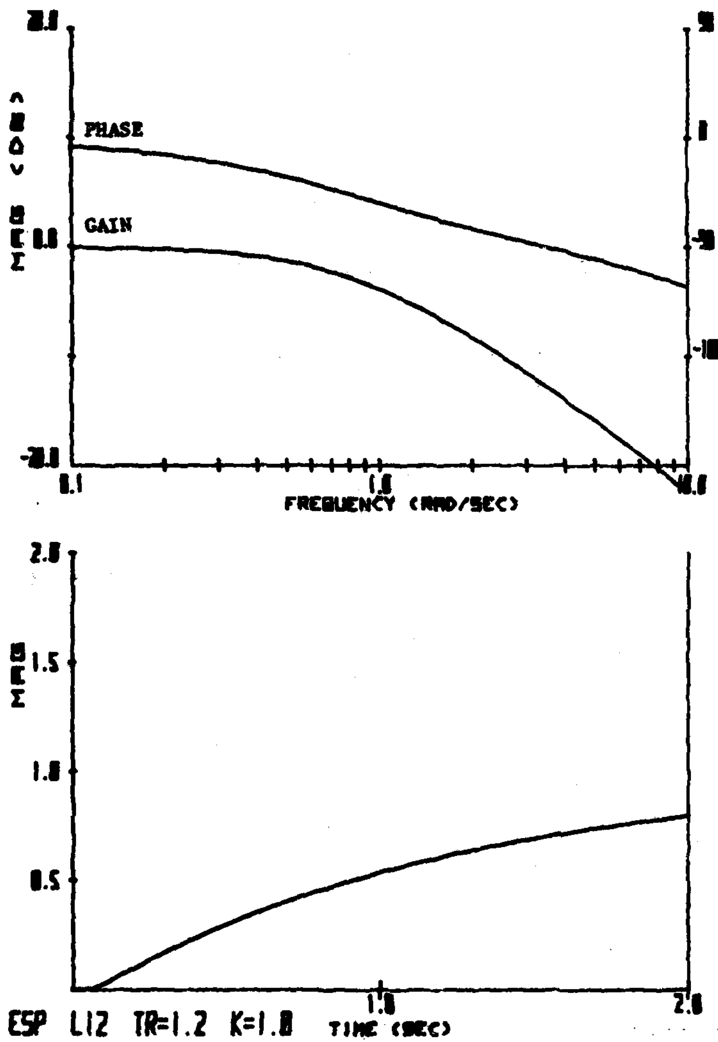
Airframe	
	L11D
τ_R (NOMINAL)	.40
τ_R (CORRECT)	.5
λ_D	2
τ	.15
P_{ss}	5
GAIN(K)	1.0

Control System
L11D
$\frac{1}{(S + 4)}$

FIGURE D-43 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L12-1 - Bank angle response slow, heavy lateral forces. PR = 5



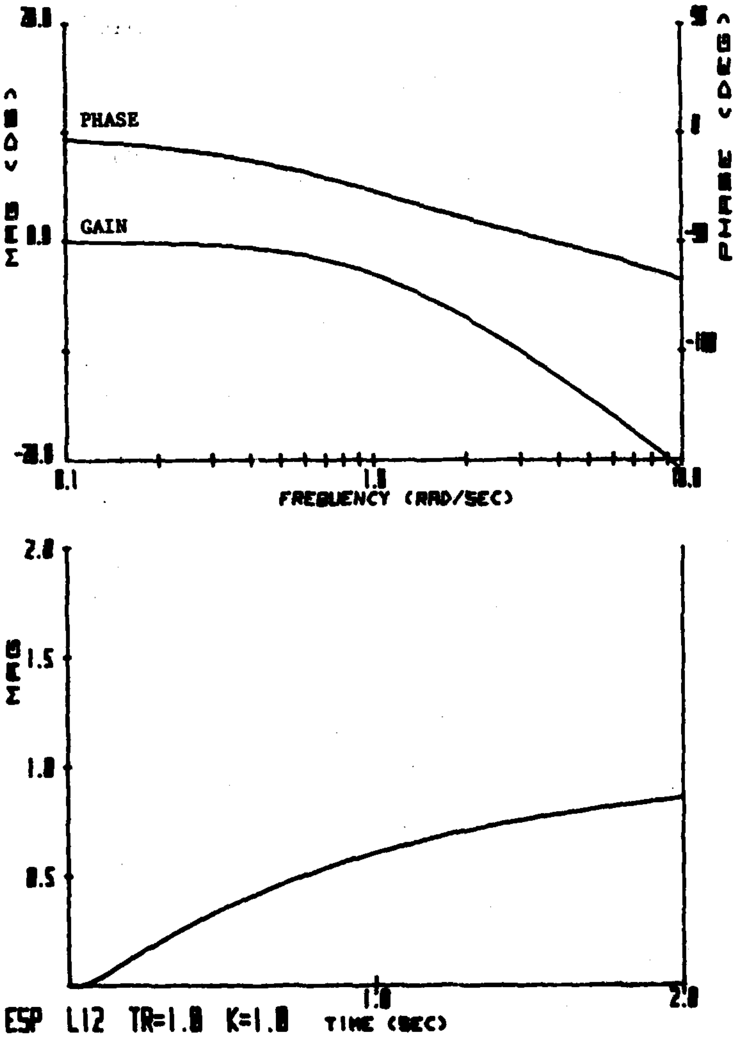
Airframe	
	L12-1
τ_R (NOMINAL)	0.9
τ_R (CORRECT)	1.2
λ_D	20
τ	-
P_{ss}	6
GAIN(K)	1.0

Control System
L12-1
$\frac{0}{(S + 4)}$

FIGURE D-44 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L12-2 - Aggressive sideslip showed lag and overcontrol tendency. PR = 4



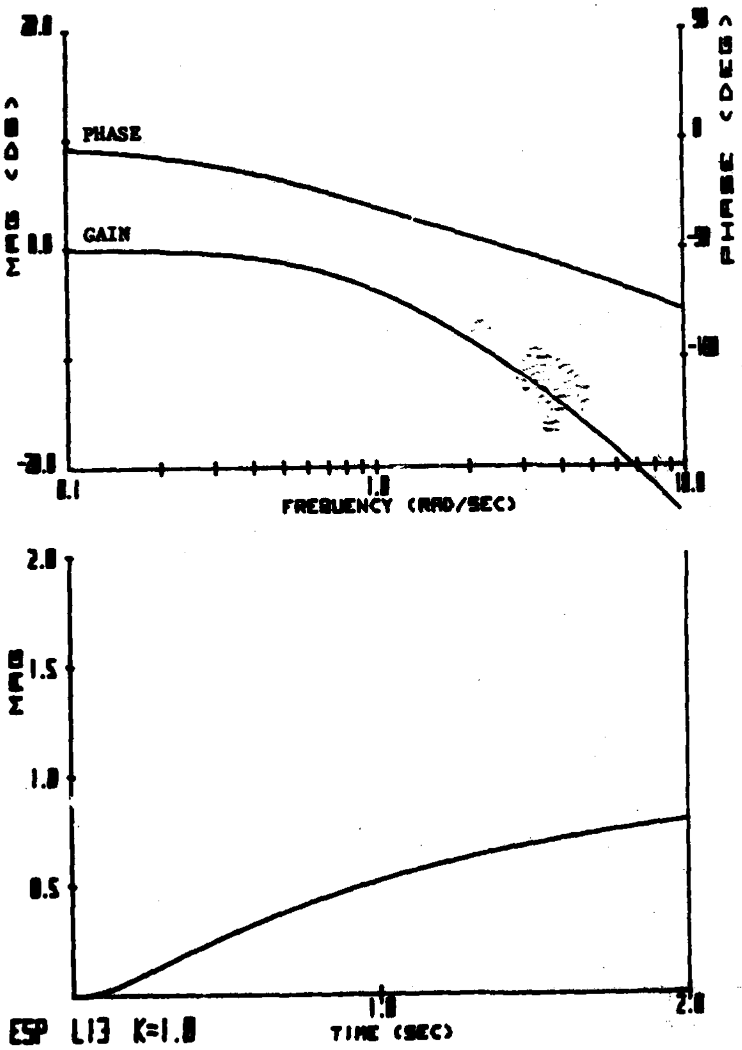
Airframe	
	L12-2
τ_R (NOMINAL)	0.9
τ_R (CORRECT)	1.0
λ_D	20
τ	-
P_{ss}	6
GAIN(K)	1.0

Control System
L12-2
$\frac{0}{(S + 4)}$

FIGURE D-45 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L13 - Sluggish initial response in sidesteps, tended to overcontrol. PR = 4.



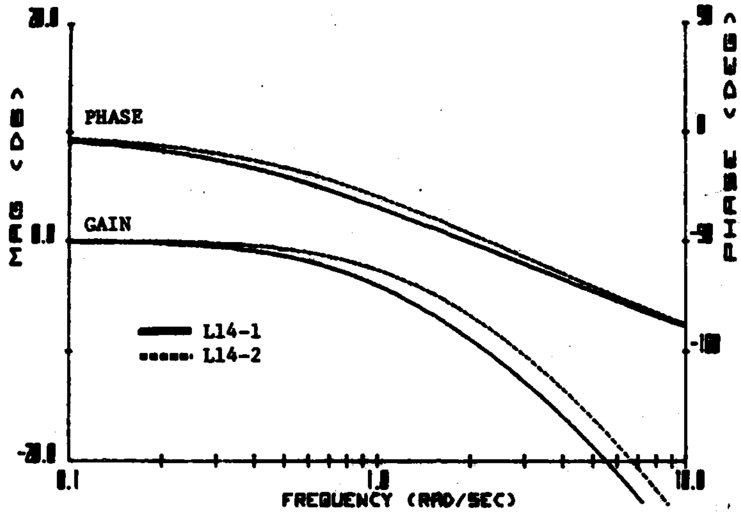
Airframe	
	L13
τ_R (NOMINAL)	.9
τ_R (CORRECT)	1.2
λ_D	10
τ	-
P_{ss}	6
GAIN(K)	1.0

Control System
L13
$\frac{0}{(S + 4)}$

FIGURE D-46 Analytical Characteristics - Roll Rate Response and Step Time History

<u>**PILOT COMMENTS**</u>

L14-1 - Bank angle required lot of lead to fly eithout overshoot. PR = 5
L14-2 - Sidestep was difficult, roll control not acceptable. PR = 7



Airframe	
	L14-1/L14-2
τ_R (NOMINAL)	0.9
τ_R (CORRECT)	1.2/0.9
λ_D	5
τ	-
P_{ss}	6
GAIN(K)	1.0

Control System
L14
$\frac{0}{(S + 4)}$

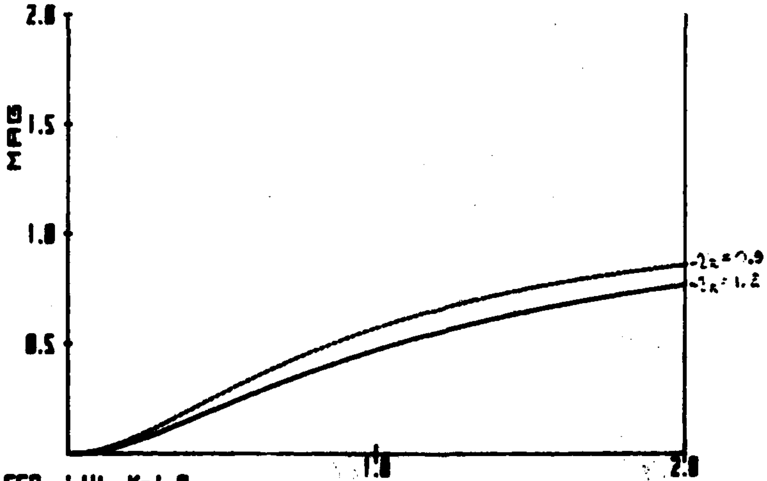
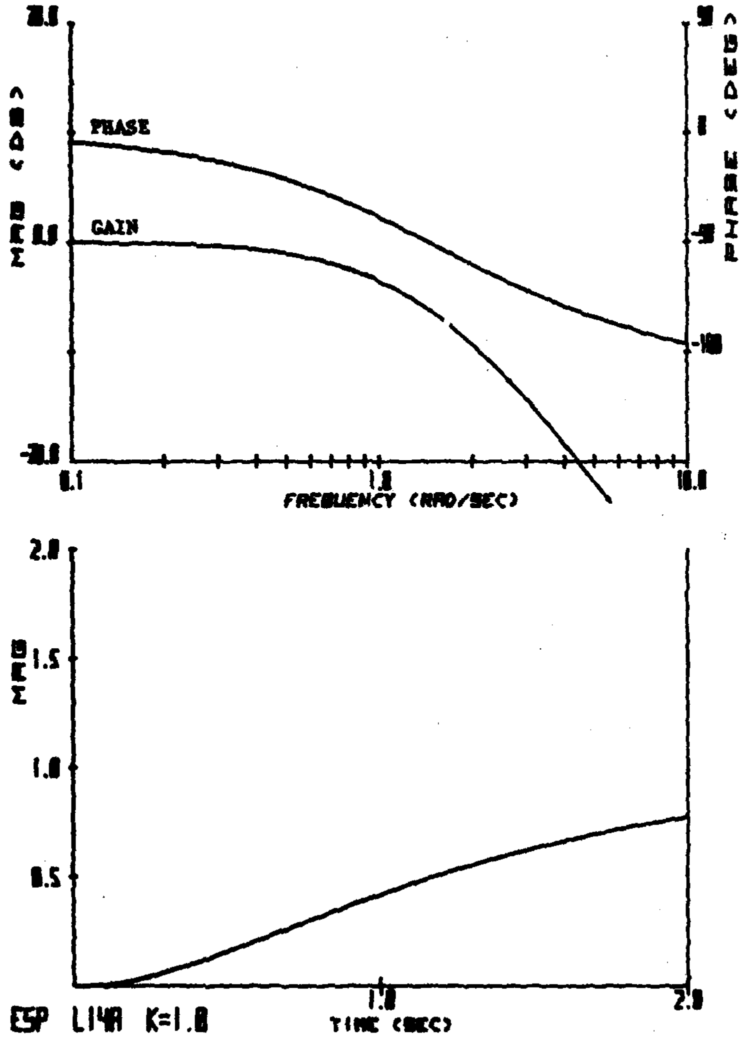


FIGURE D-47 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L14A - Bank angle control not satisfactory, slow response. PR = 7



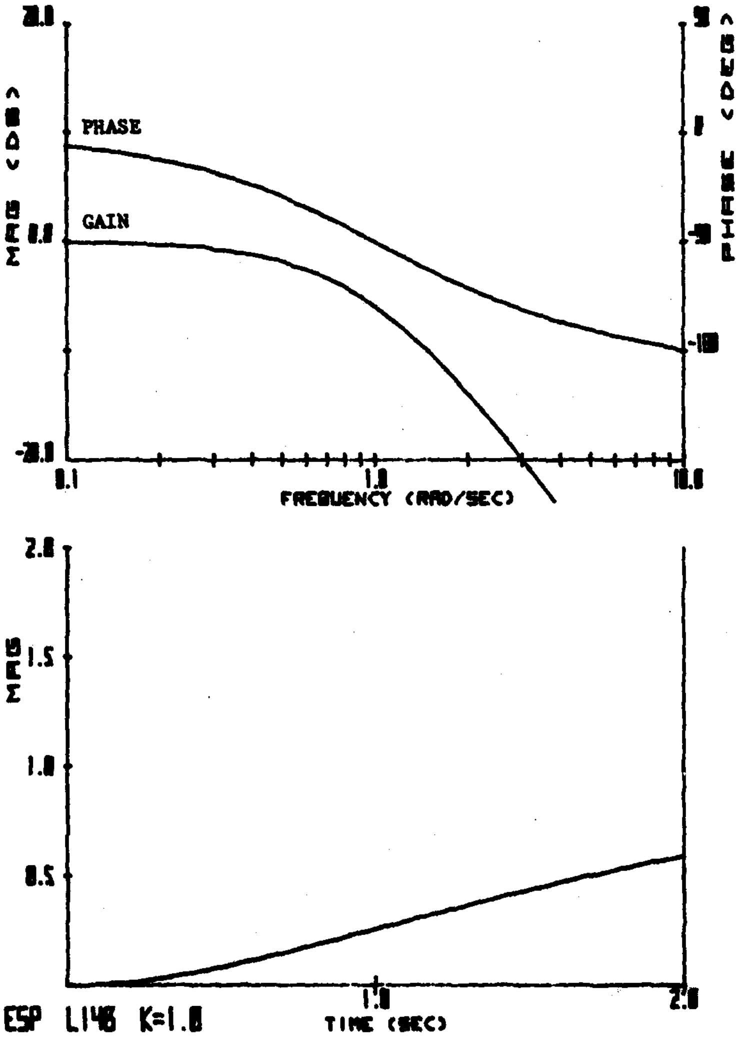
Airframe	
	L14A
τ_R (NOMINAL)	.90
τ_R (CORRECT)	.9
λ_D	2
τ	0
P_{ss}	7
GAIN(K)	1.0

Control System
L14A
$\frac{0}{(S + 4)}$

FIGURE D-40 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L14B - Bank angle control unsatisfactory, overcontrolled. PR = 10



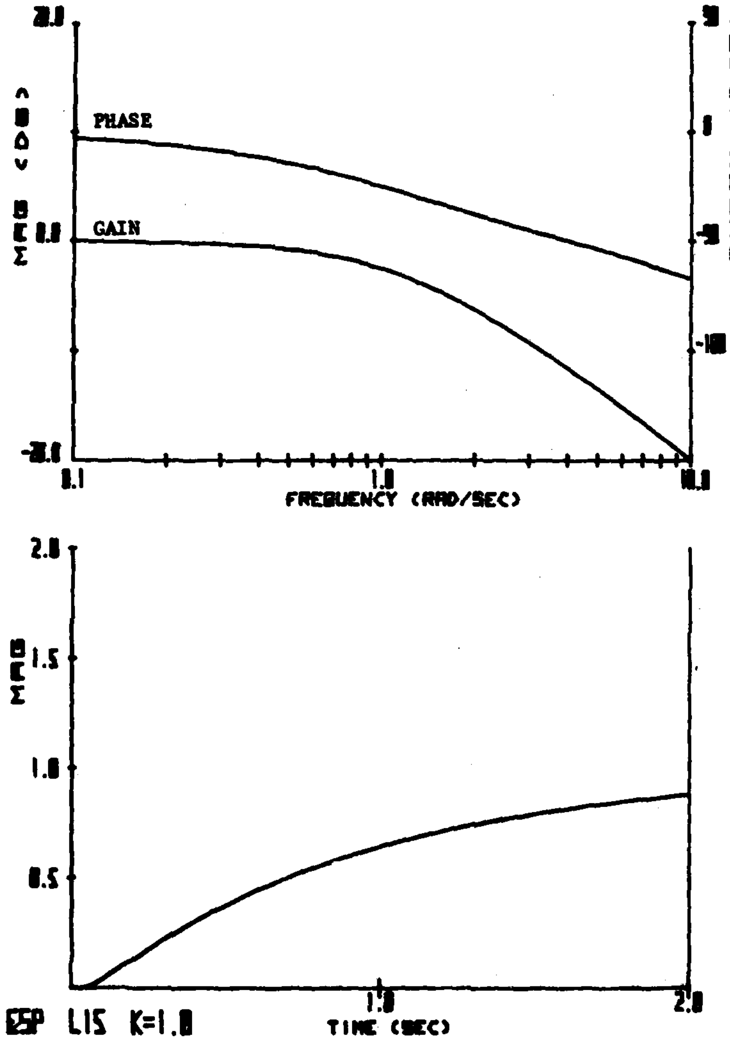
Airframe	
	L14B
τ_R (NOMINAL)	0.9
τ_R (CORRECT)	1.2
λ_D	1
τ	-
P_{ss}	6
GAIN(K)	1.0

Control System
L14B
$\frac{0}{(S + 4)}$

FIGURE D-49 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L15 - Wanted a more response roll control. PR = 4



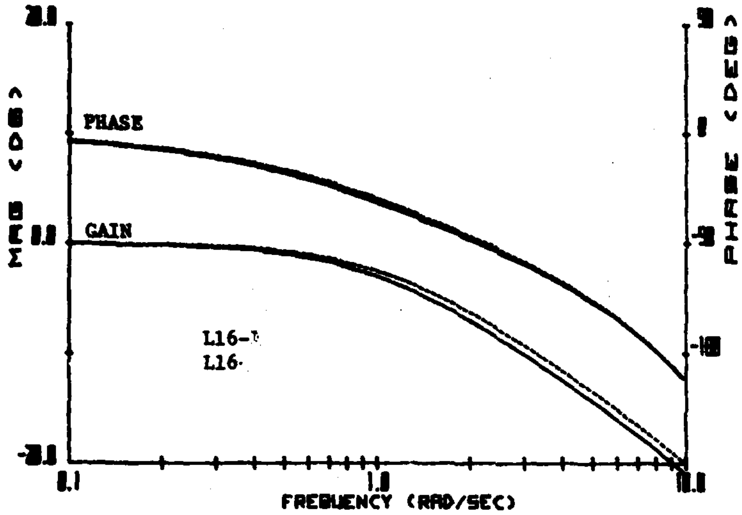
Airframe	
	L15
τ_R (NOMINAL)	0.9
τ_R (CORRECT)	.9
λ_D	20
τ	.09
P_{ss}	9
GAIN(K)	1.0

Control System
L15
$\frac{1}{(S + 4)}$

FIGURE D-50 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L16-1 - Slightly heavy in roll response PR = 3
L16-2 - Quick to respond but not predictable PR = 4



	Airframe
	L16-1/L16-2
τ_R (NOMINAL)	0.9
τ_R (CORRECT)	1.0/0.9
λ_D	20
τ	.14
P_{ss}	6
GAIN(K)	1.0

Control System
L16
$\frac{1}{(S + 4)}$

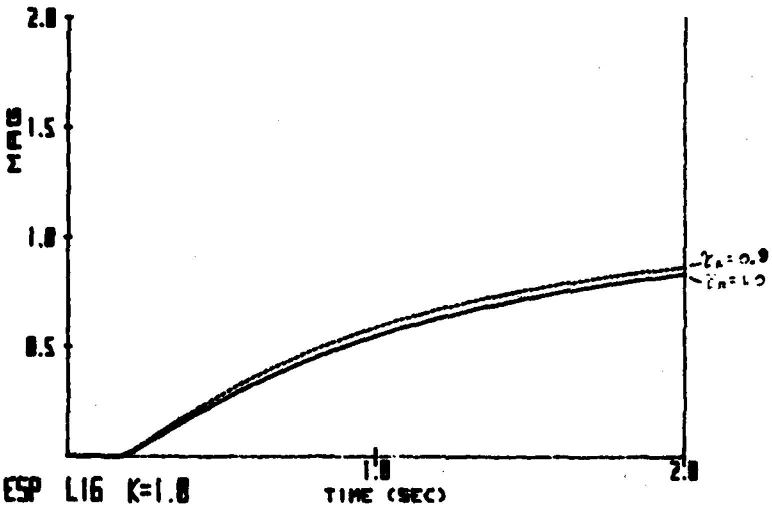
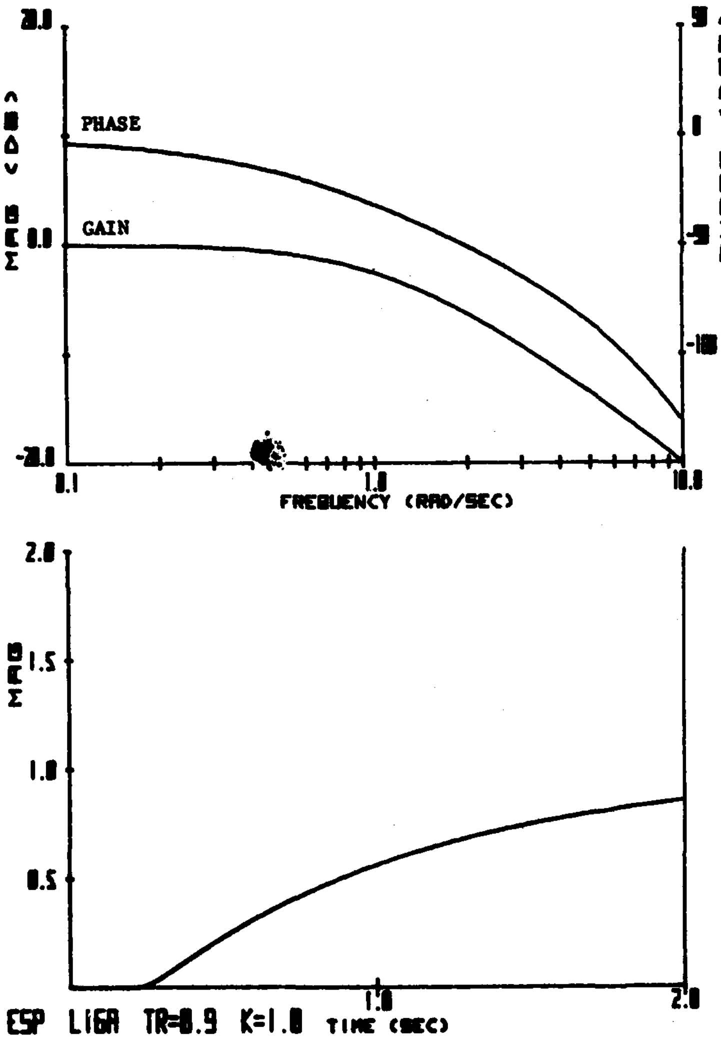


FIGURE D-51 Analytical Characteristics - Roll Rate Response and Step Time History

PILOT COMMENTS

L16A - Initial delay in bank angle control then quick response and overshoot.   PR = 8



Airframe	
	L16A
τ_R (NOMINAL)	0.9
τ_R (CORRECT)	.9
λ_D	20
τ	.20
P_{ss}	6
GAIN(K)	1.0

Control System
L16A
$\frac{1}{(S + 4)}$

FIGURE D-52 Analytical Characteristics - Roll Rate Response and Step Time History

APPENDIX E

FLIGHT TIME HISTORIES AND FREQUENCY RESPONSE

The flight time histories for a selected group of configurations with either longitudinal or lateral frequency response characteristics are presented in Figures E-1 through Figure E-48. A Fast Fourier Transform method of analysis is used to convert the twenty seconds just prior to touchdown in the landing tasks from time reference data to frequency domain. The No. 2 Landing Task, defined in Section V, is selected as typical for analysis of response characteristics of each configuration. Examples of Landing Tasks No. 1, No. 2, and No. 3 are shown in Figures E-18, E-19 and E-20. The pilot ratings are based on the composite impression of the three types of approach and landing tasks.

Time history plots include six parameters pertinent to the analysis of pitch rate and roll rate responses of the configurations. The Bode plot presentations represent the predicted responses based on the analytical descriptions for each configuration (solid lines). Circled points are fast fourier calculations using the flight time history data.

Generally, the predicted characteristics and test data compare well. Differences in gain or phase at the higher frequencies can be due to linear assumptions for the analytical functions versus the non-linear stick breakout force inherent in the measured flight data. Also, phase angles for the analytical response characteristics would be more negative at the high frequencies when the time delay increment for Butterworth filters is corrected in the configurations with time delay circuits (i.e. the $\triangleleft \xi \approx -15^\circ$ at ω_{sp} = 10 rad/sec).

The majority of the selected group is from flights with Pilot A. A few cases are included with Pilots B and C, as indicated on the plots, to illustrate rating repeatability and frequency response characteristics for the same configuration, when flown by different pilots. Pilots A and B are compared with configurations P6, P10D and P12. Pilots B and C are shown in configuration P15A.

CONFIG P4 - LANDING NO. 2 FLT 2071 REC NO. 6

HOS (Adv Fighter, 30° Flap)

Pilot A; PR 3

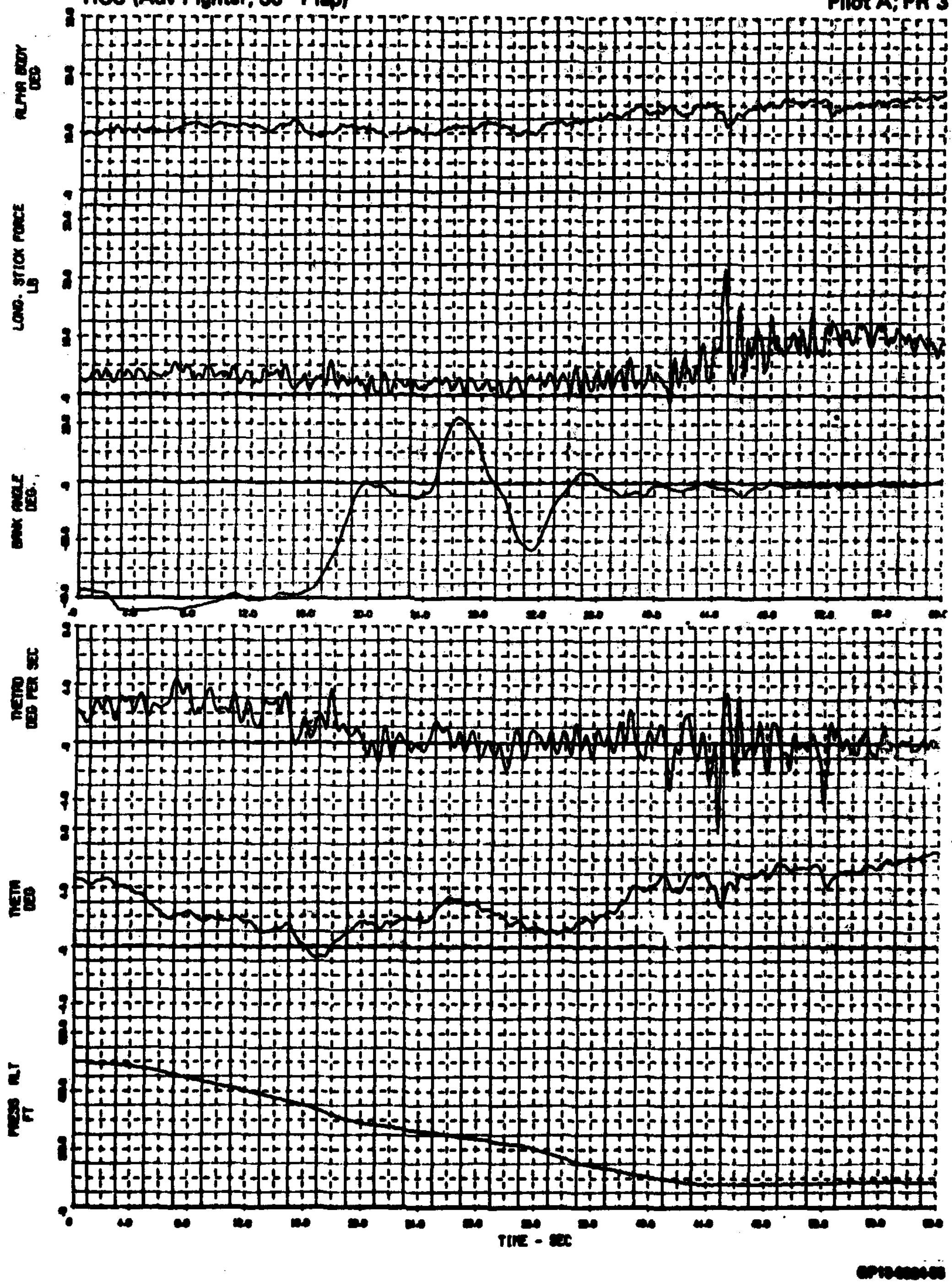


Figure E-1a. Flight Characteristics - Time History

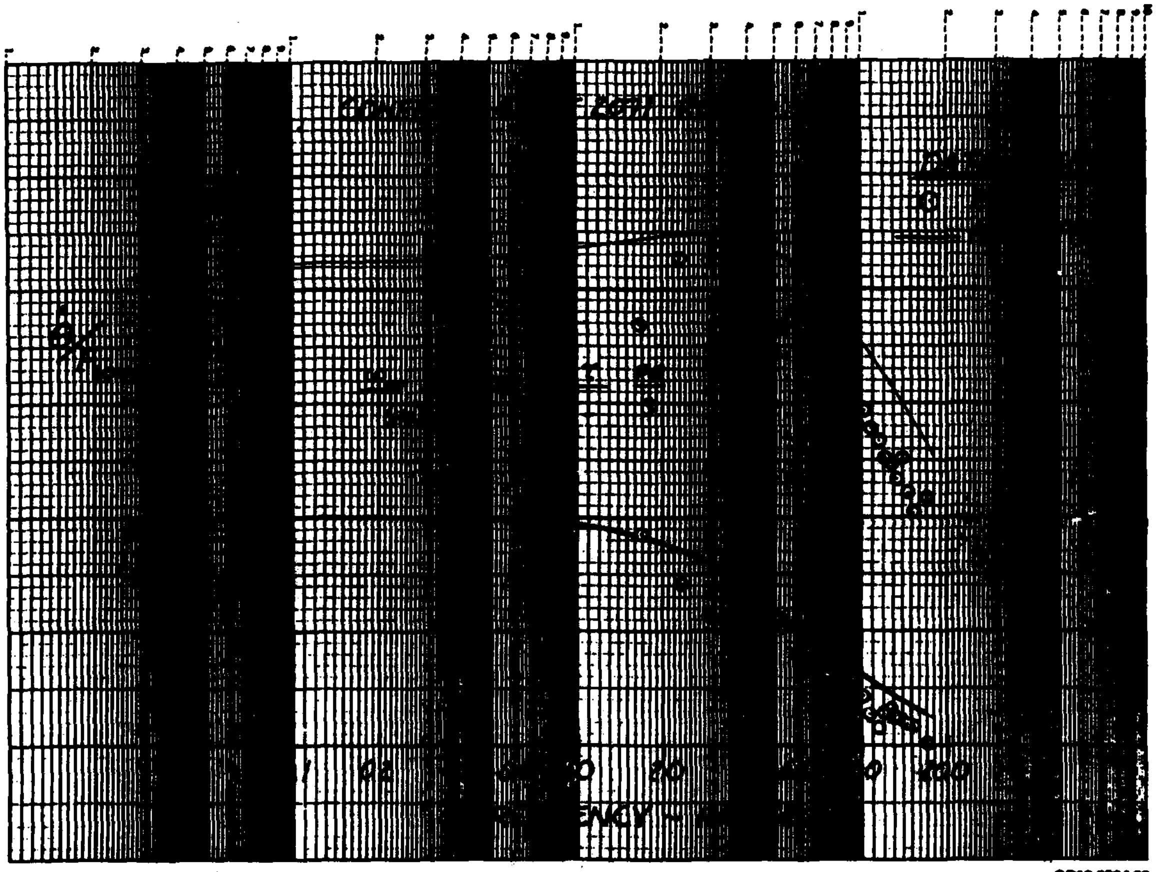
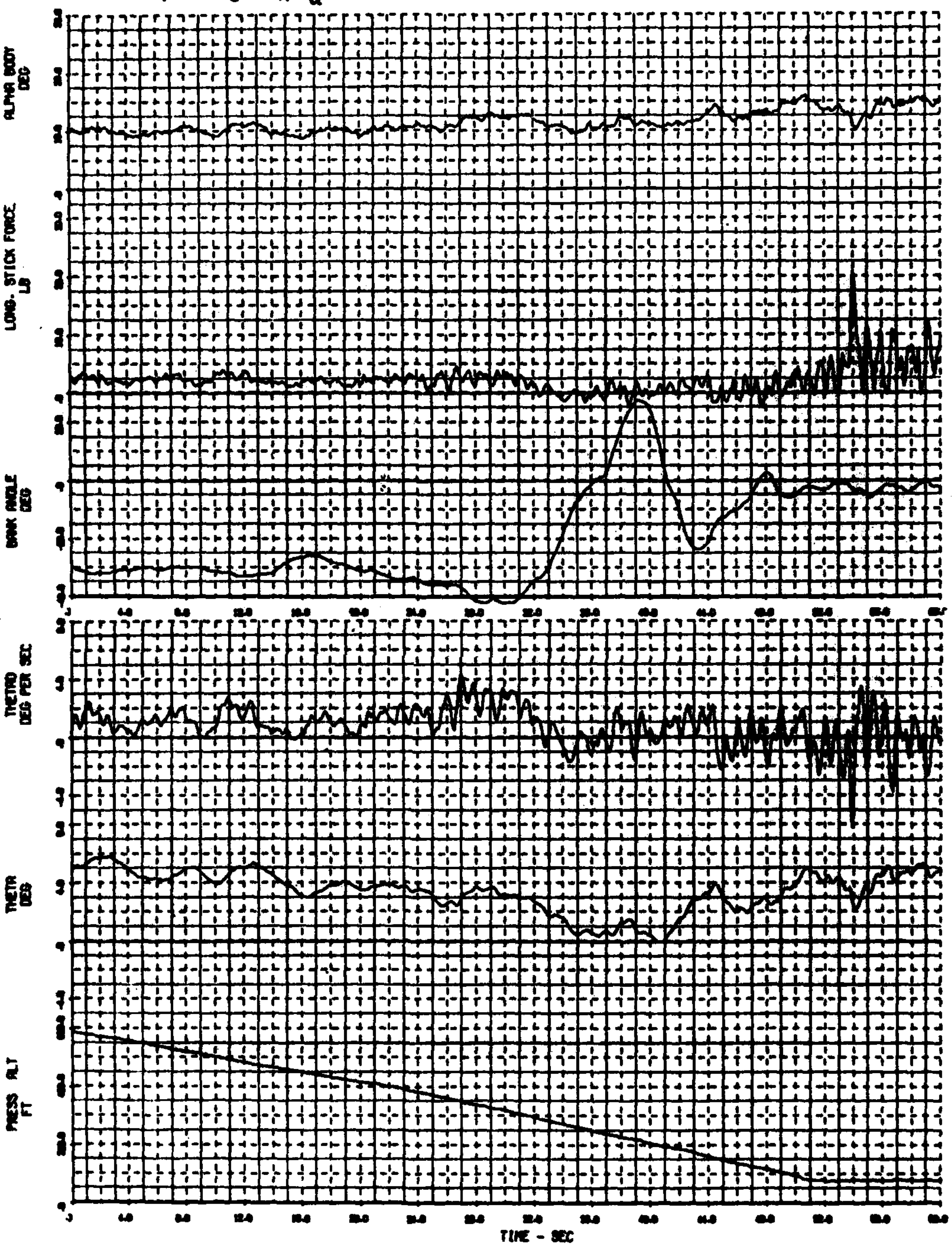


Figure E-1b. Flight Characteristics - Pitch Rate Response

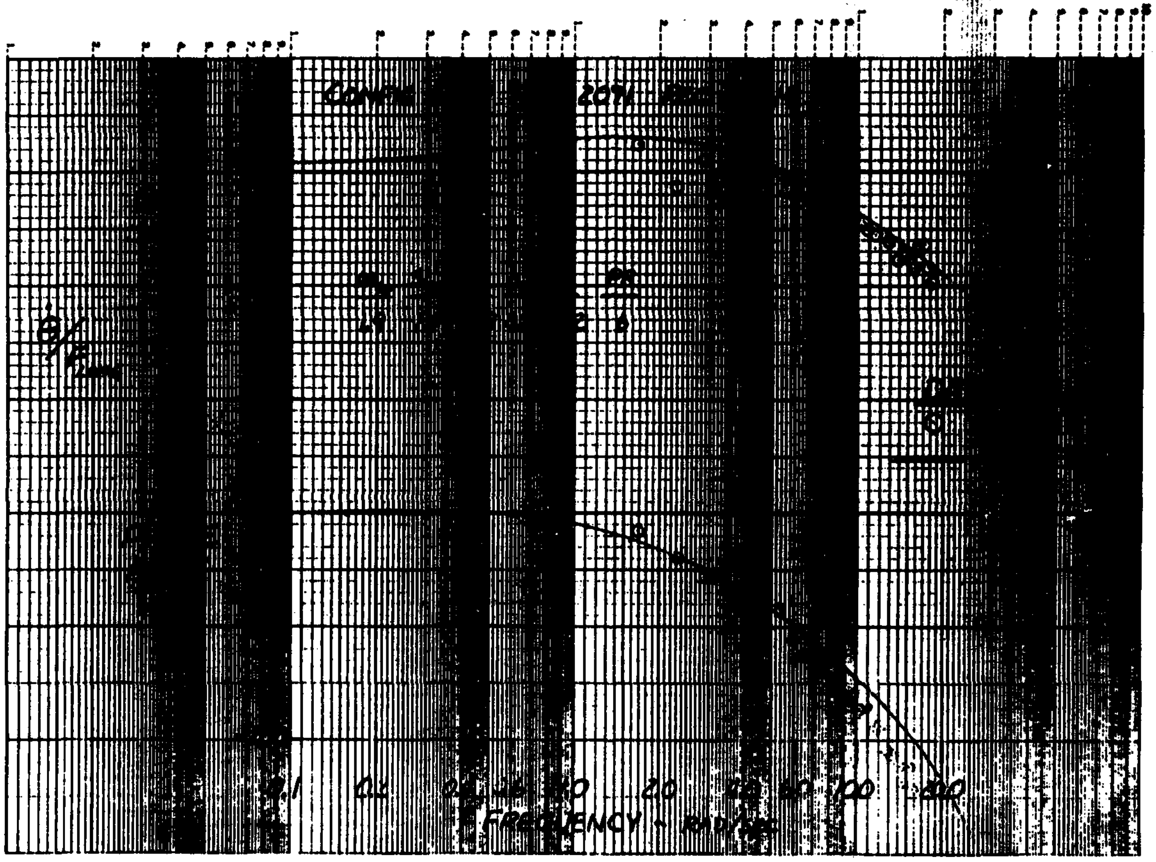
CONFIG P5-/ -LANDING NO. 2 FLT 2071 REC NO. 14

ES for P4 (Adv Fighter), L_α Fixed — Pilot A; PR 6



GP13-0284-40

Figure E-2a. Flight Characteristics - Time History

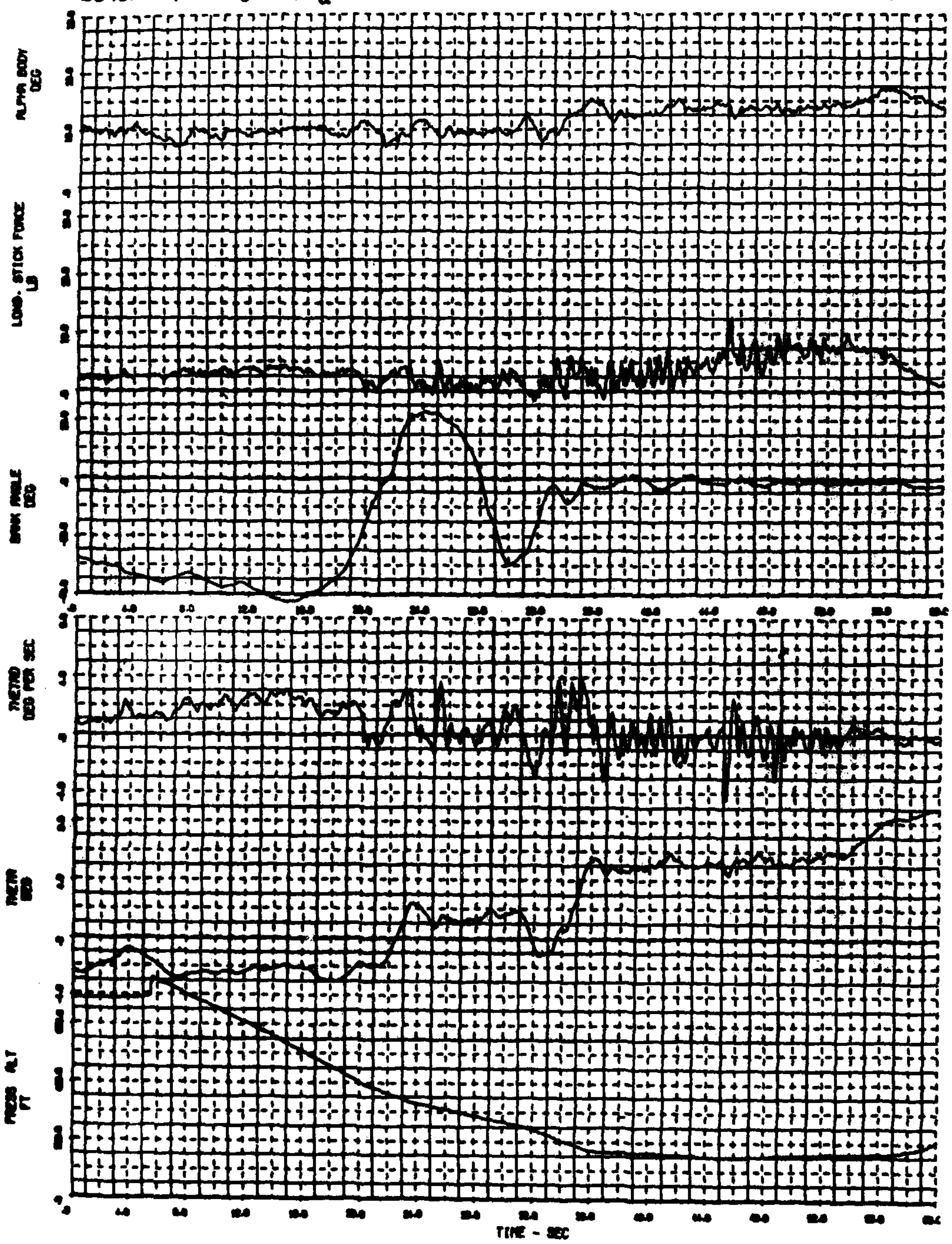


GP13-0284-01

Figure E-2b. Flight Characteristics - Pitch Rate Response

CONFIG PS-2 - LANDING NO. 2 FLT 2073 REC NO. 14

ES for P4 (Adv Fighter), L_α Fixed — Pilot B; PR 6



GP19-0284-62

Figure E-3a. Flight Characteristics - Time History

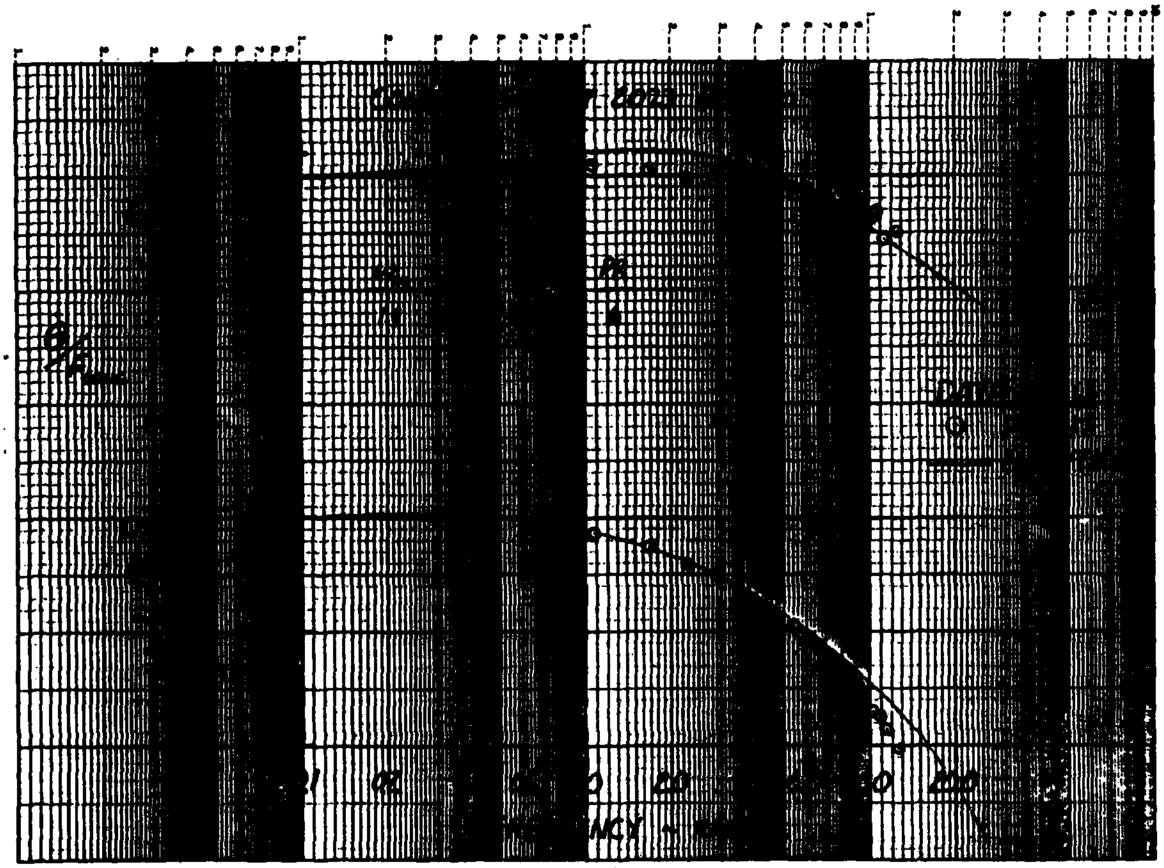


Figure E-3b. Flight Characteristics - Pitch Rate Response

CONFIG PSA - LANDING NO. 2 FLT 2073 REC NO. 23

Modified ES for P4

Pilot B; PR 7

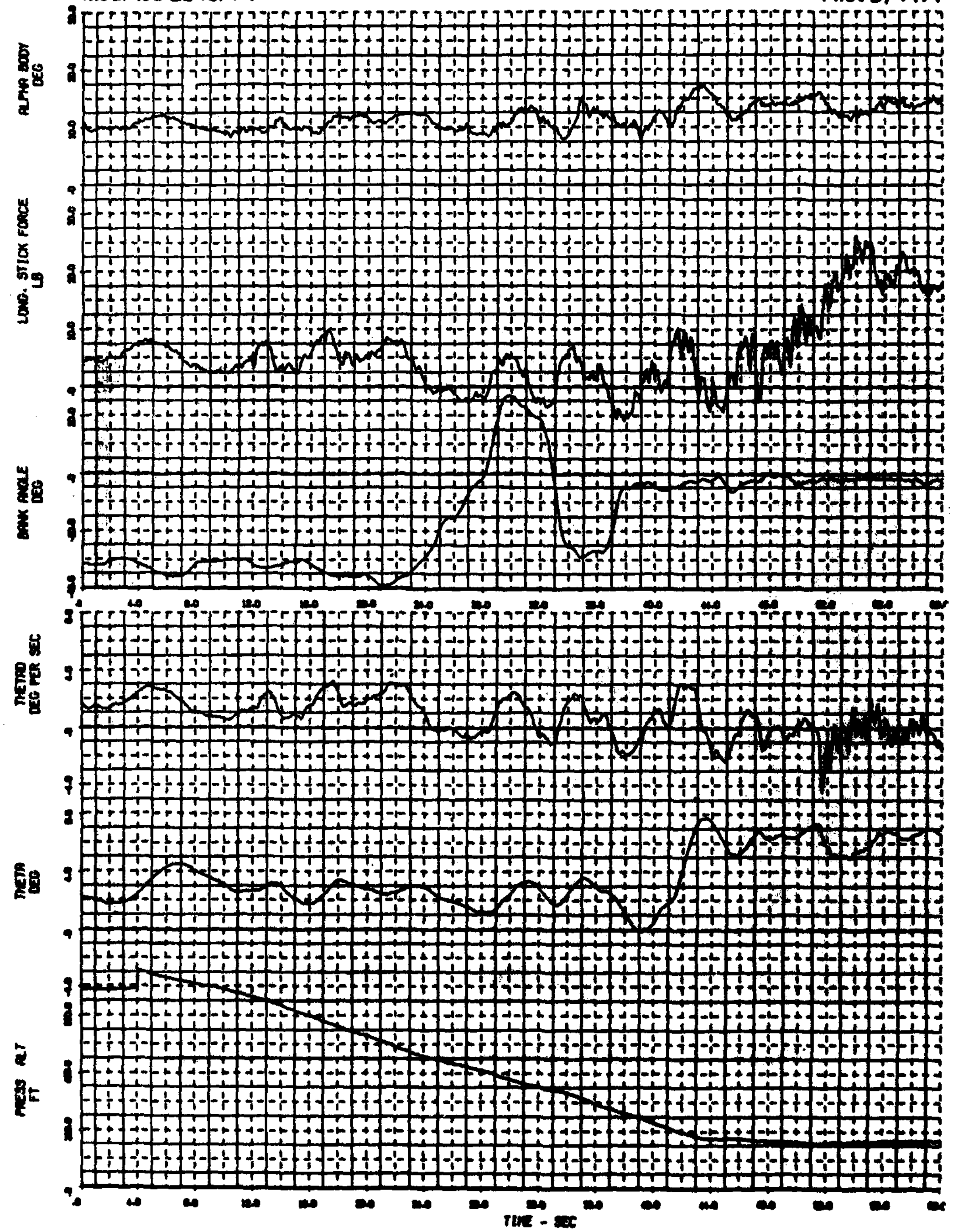
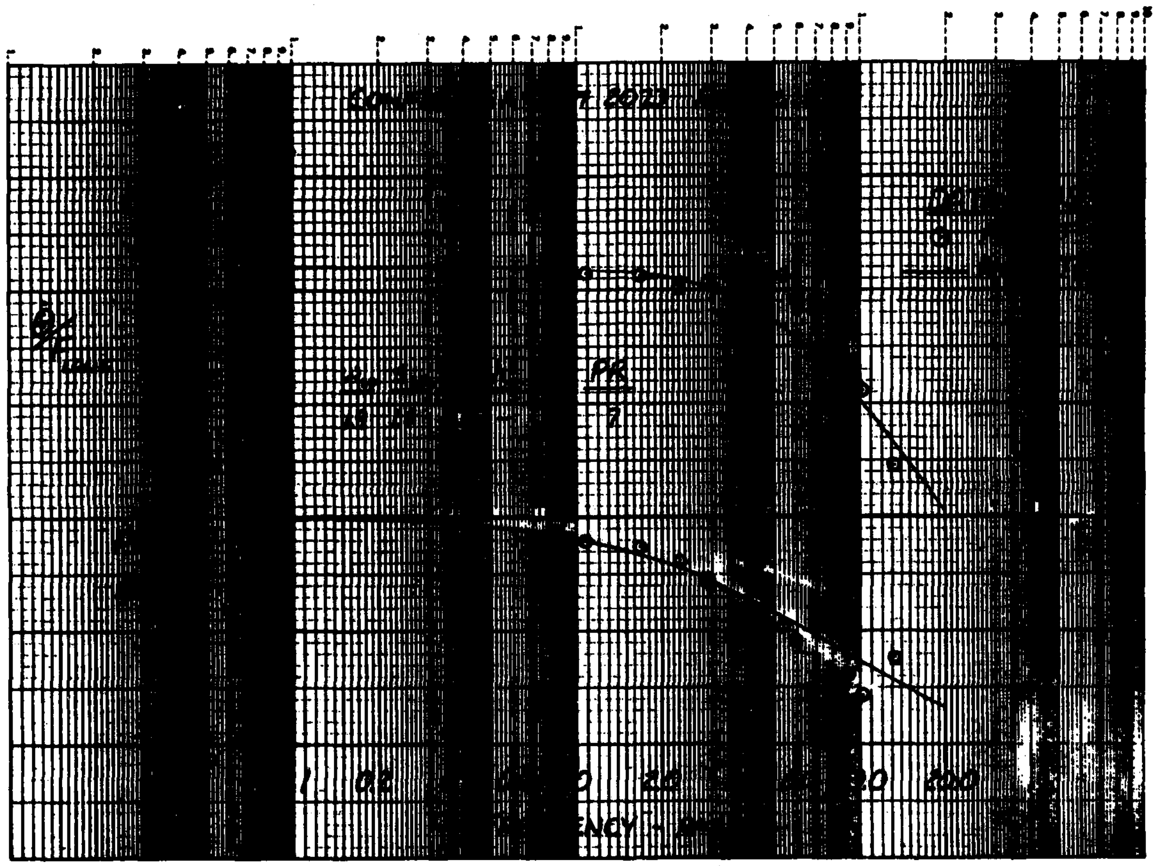


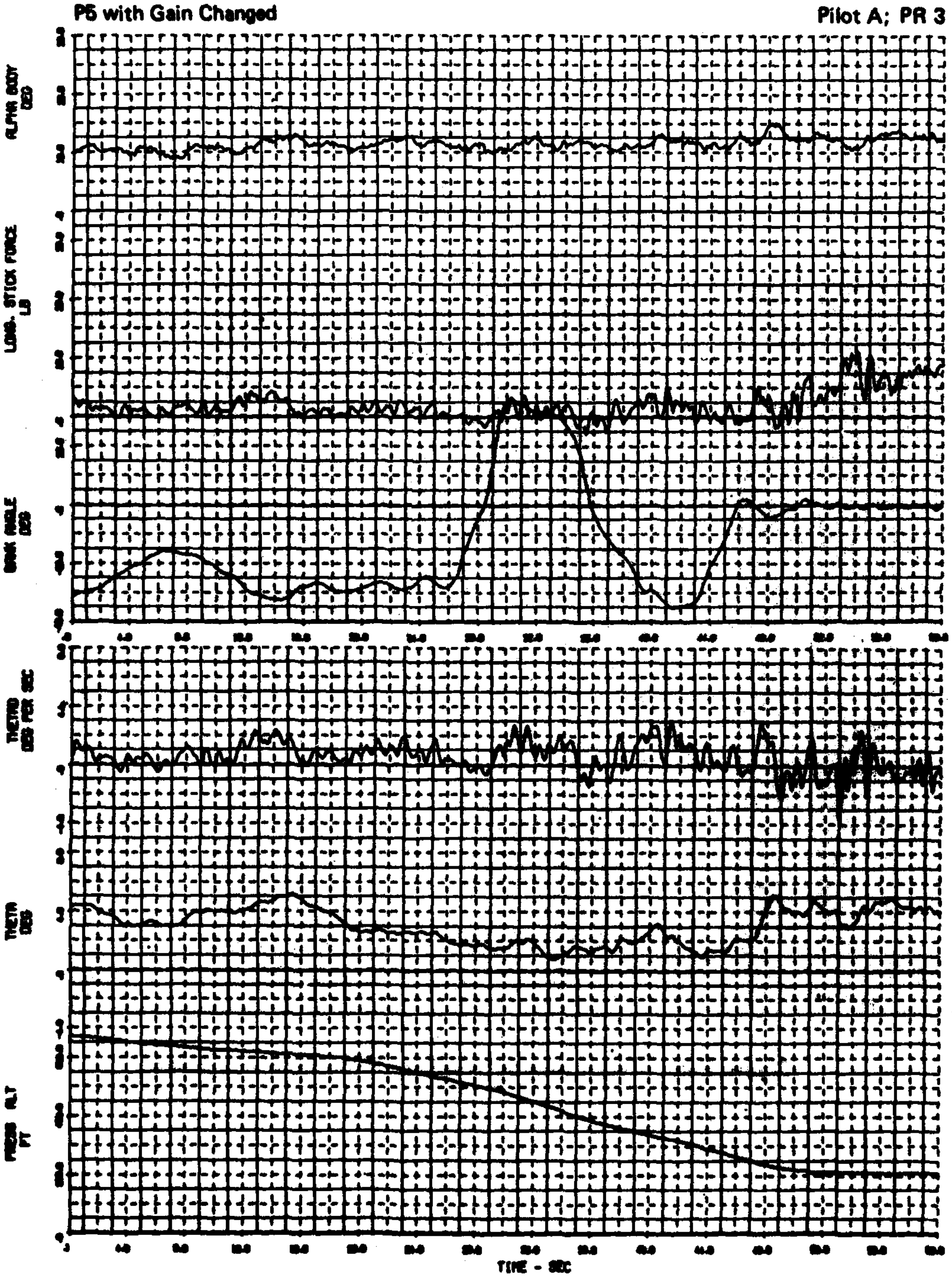
Figure E-4a. Flight Characteristics - Time History



SP13-0024-45

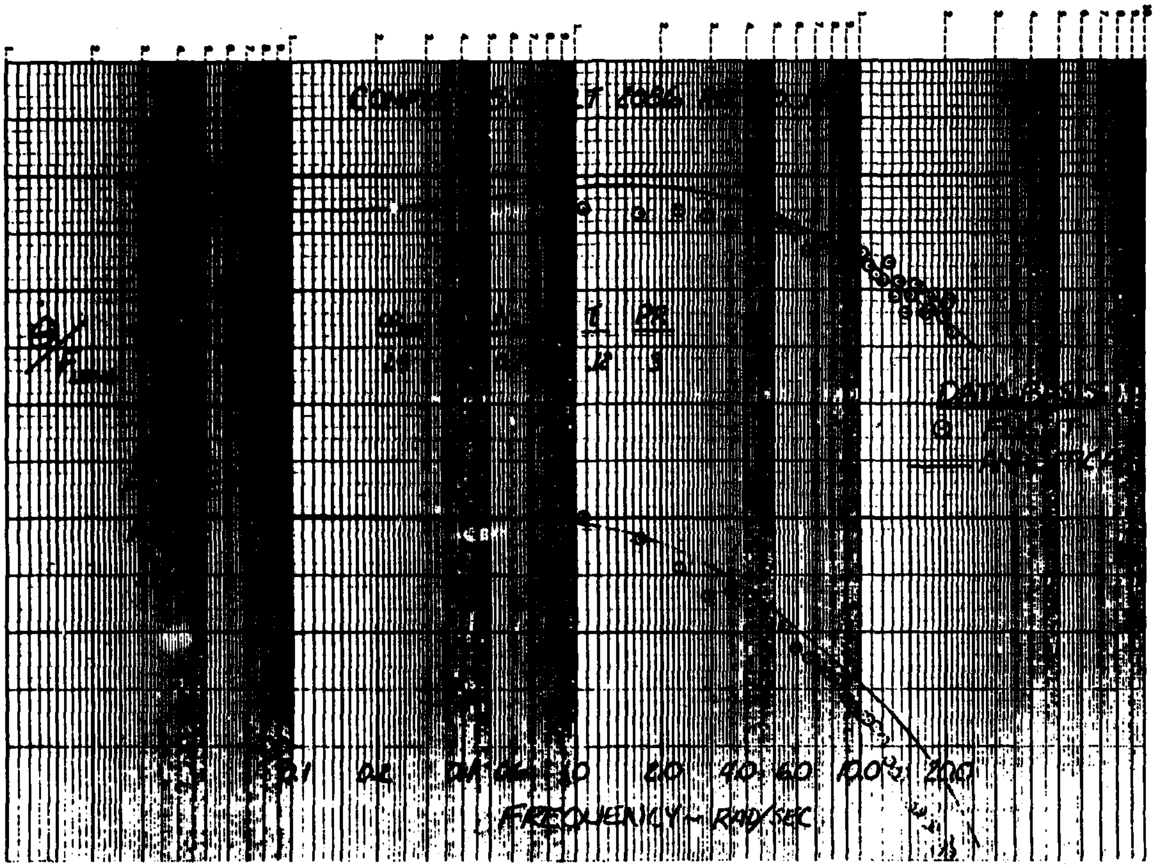
Figure E-4b. Flight Characteristics - Pitch Rate Response

CONFIG P5B -LANDING NO. 2 FLT 2086 REC NO. 16



GP13-0004-43

Figure E-8a. Flight Characteristics - Time History



GP13-0024-47

Figure E-5b. Flight Characteristics - Pitch Rate Response

CONFIG P6 -LANDING NO. 2 FLT 2071 REC NO. 19

ES for P4 (Adv Fighter), L_{α} Free

Pilot A; PR 4

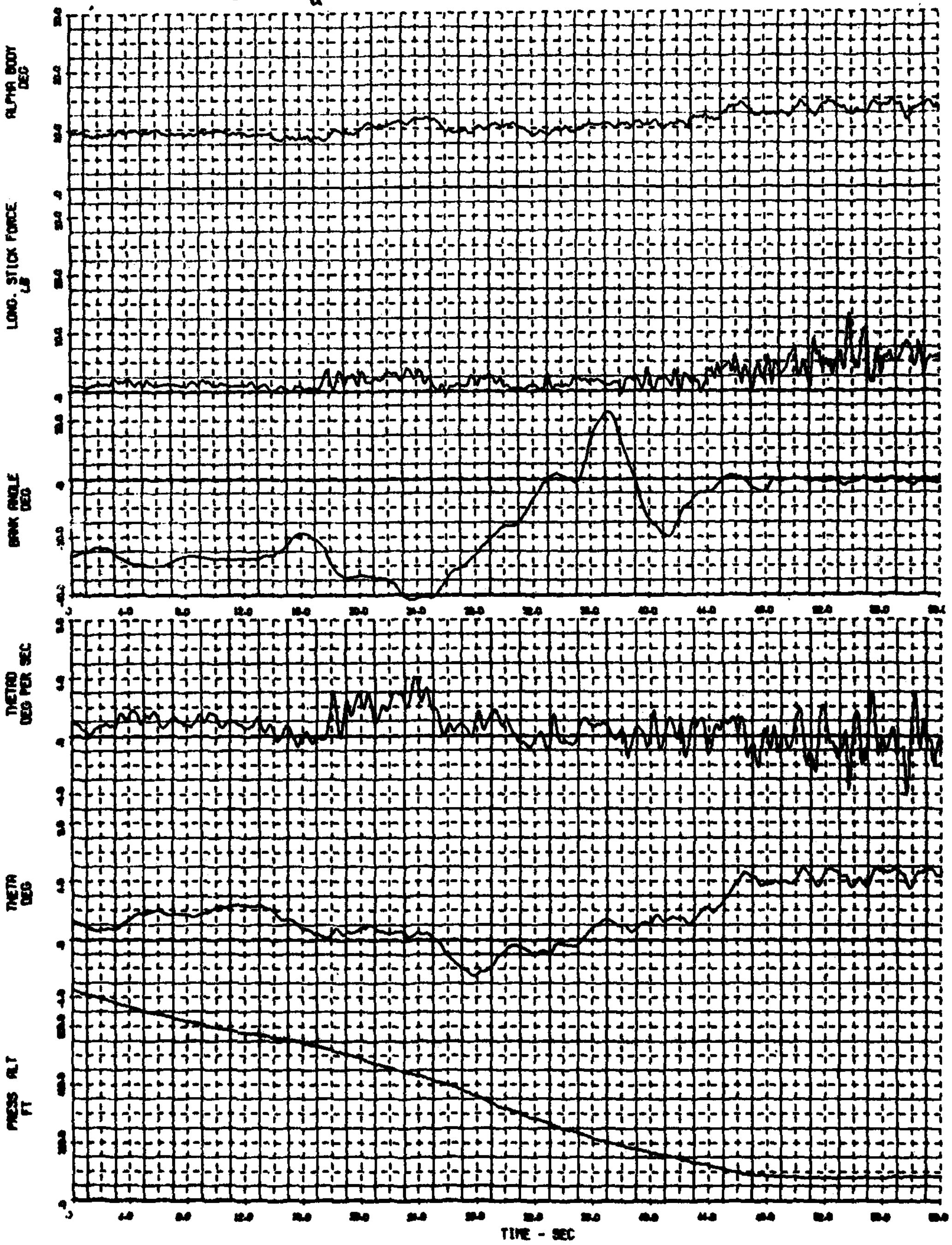


Figure E-6a. Flight Characteristics - Time History

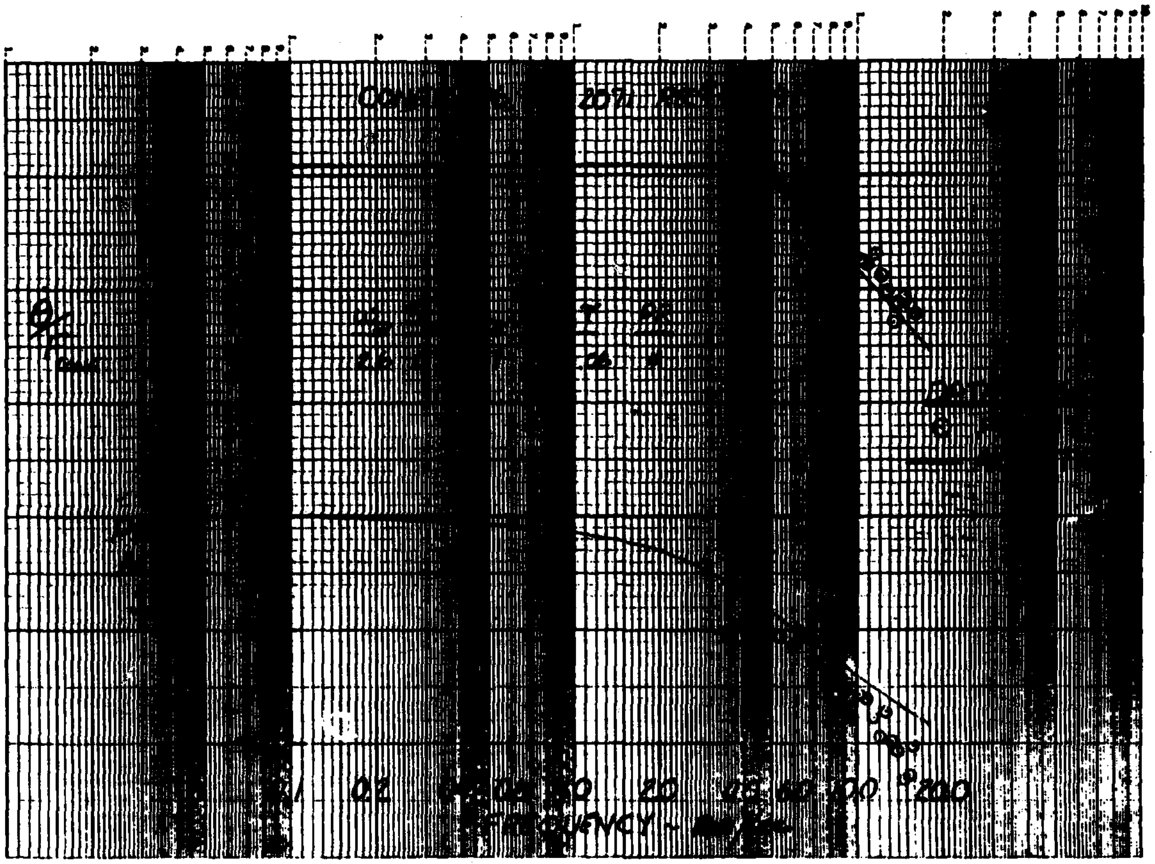
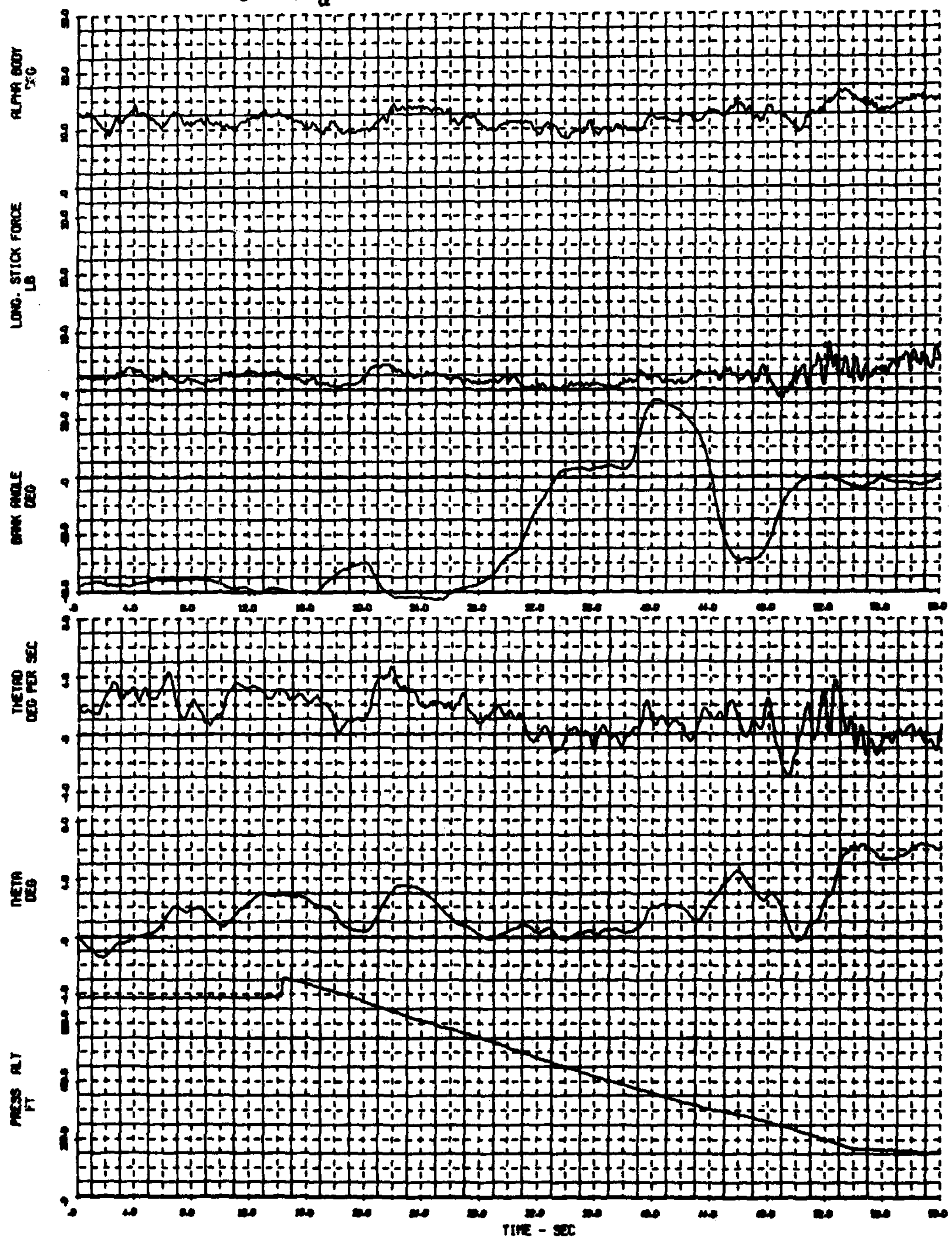


Figure E-6b. Flight Characteristics - Pitch Rate Response

CONFIG P 6 - LANDING NO. 2 FLT 2073 REC NO. 17

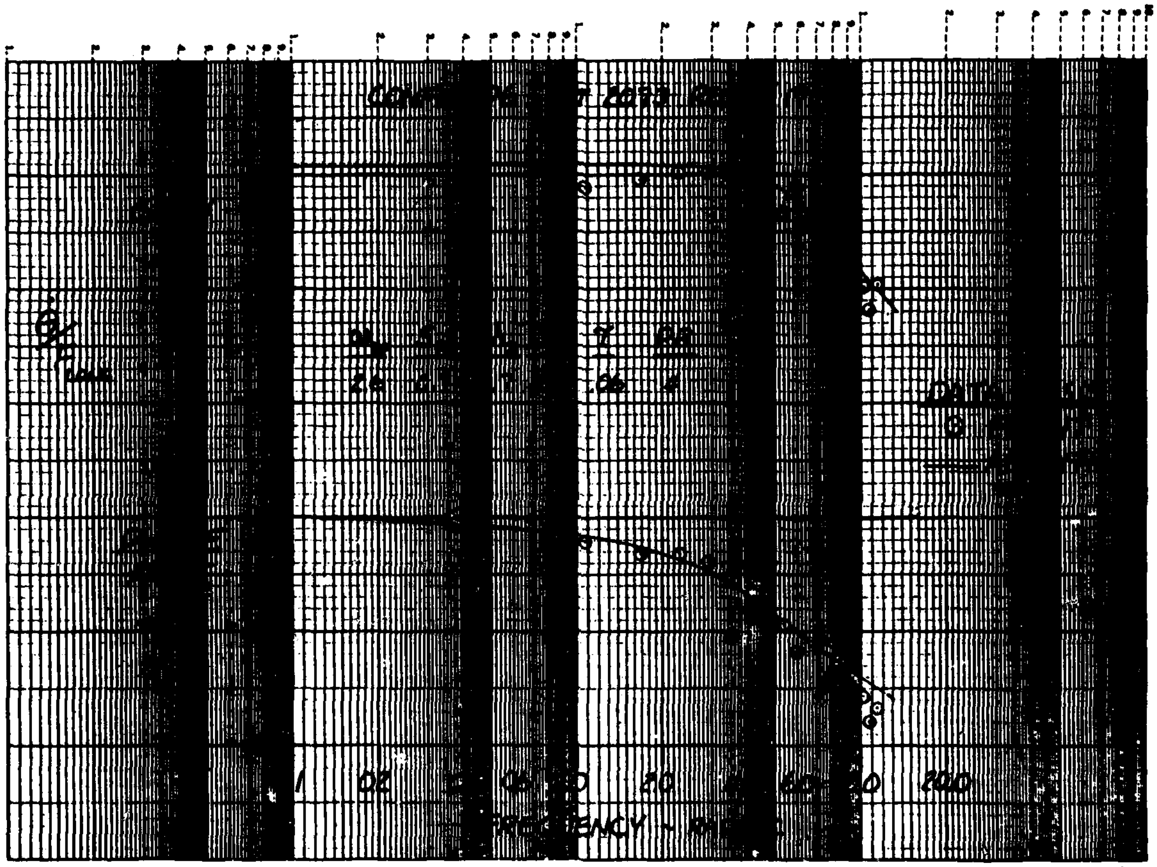
ES for P4 (Adv Fighter), L_{α} Free

Pilot B; PR 4



GP13-0884-58

Figure E-7a. Flight Characteristics - Time History



GP13-0884-51

Figure E-7b. Flight Characteristics - Pitch Rate Response

CONFIG P 7 - LANDING NO. 2 FLT 2062 REC NO. 10

HOS (LAHOS Config 2-11) Force Commands Pilot A; PR 4

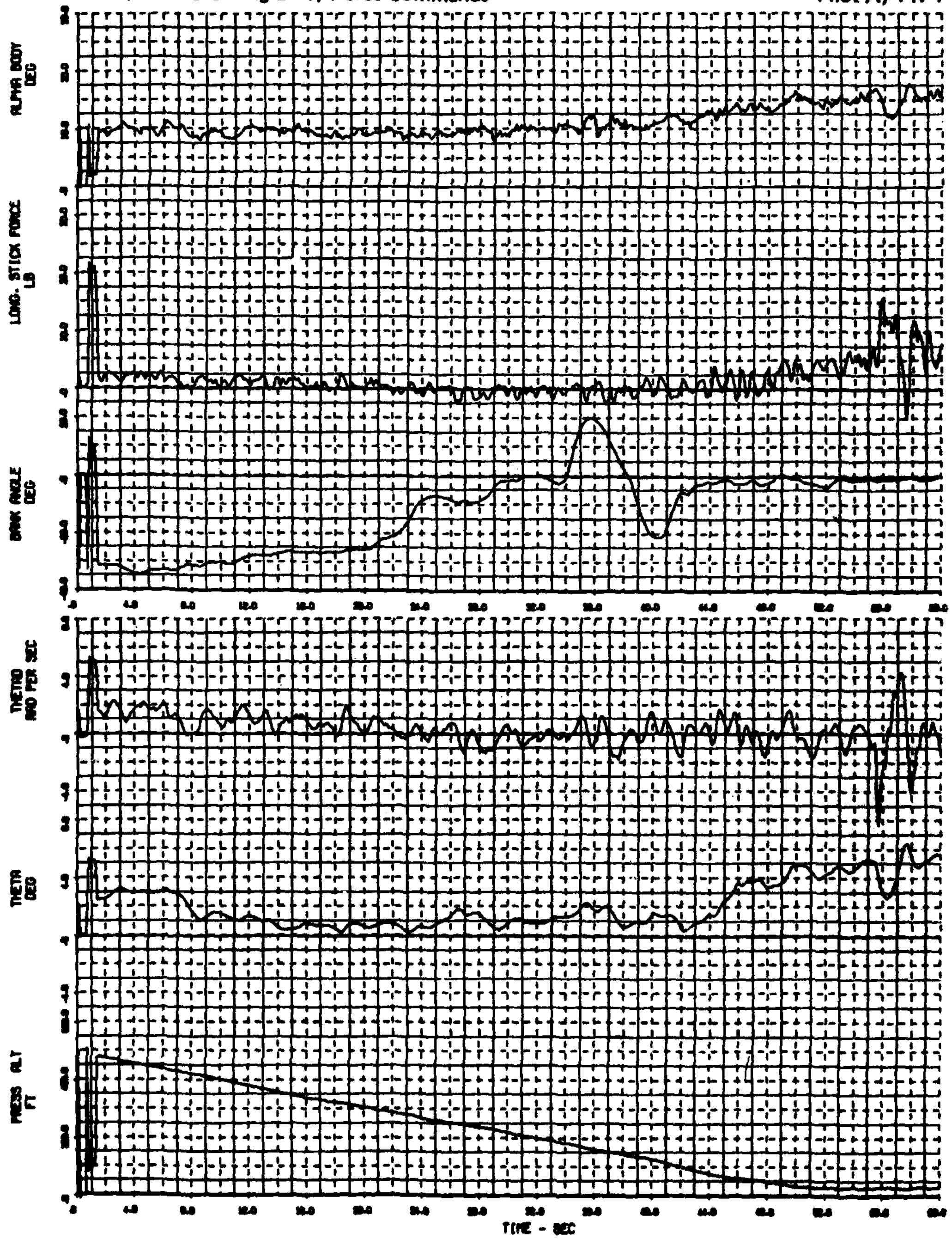
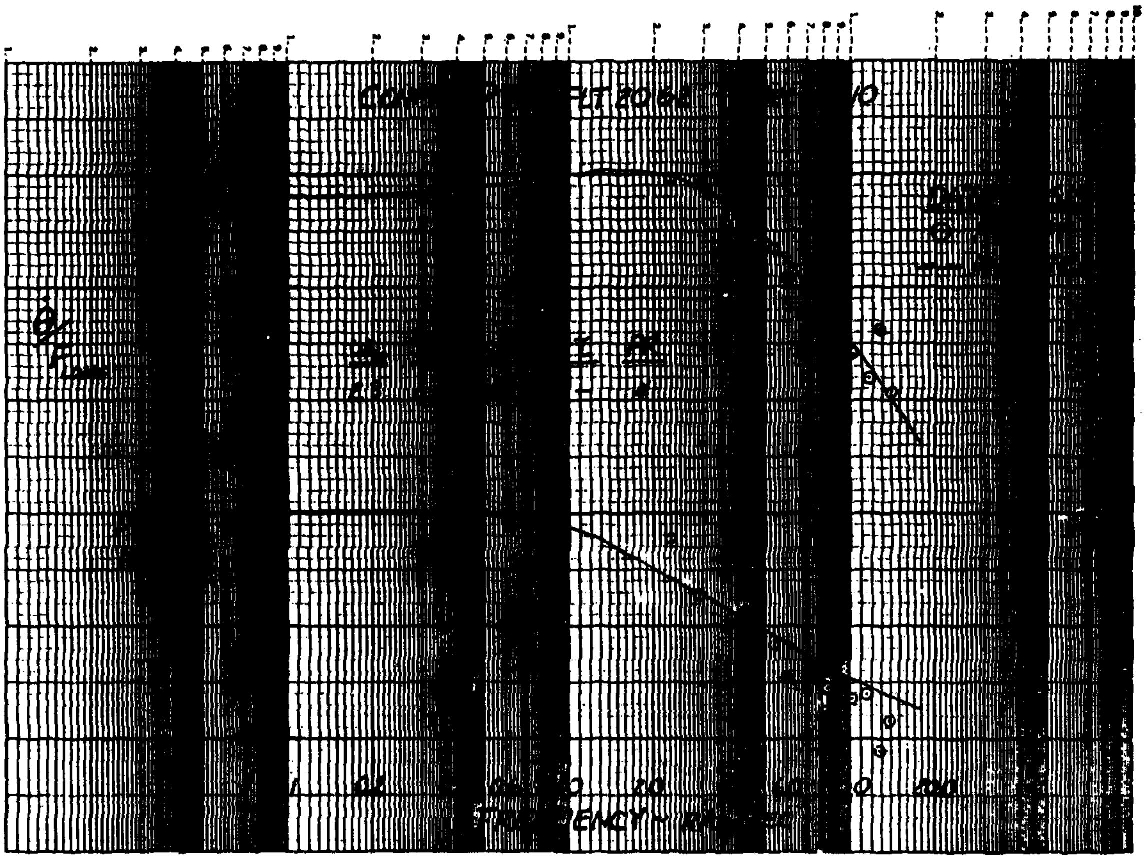


Figure E-8a. Flight Characteristics - Time History



GP13-0034-83

Figure E-8b. Flight Characteristics - Pitch Rate Response

CONFIG P 8 - LANDING NO. 2   FLT 2069 REC NO. 6

ES for P7, L_α Fixed   Pilot A; PR 5

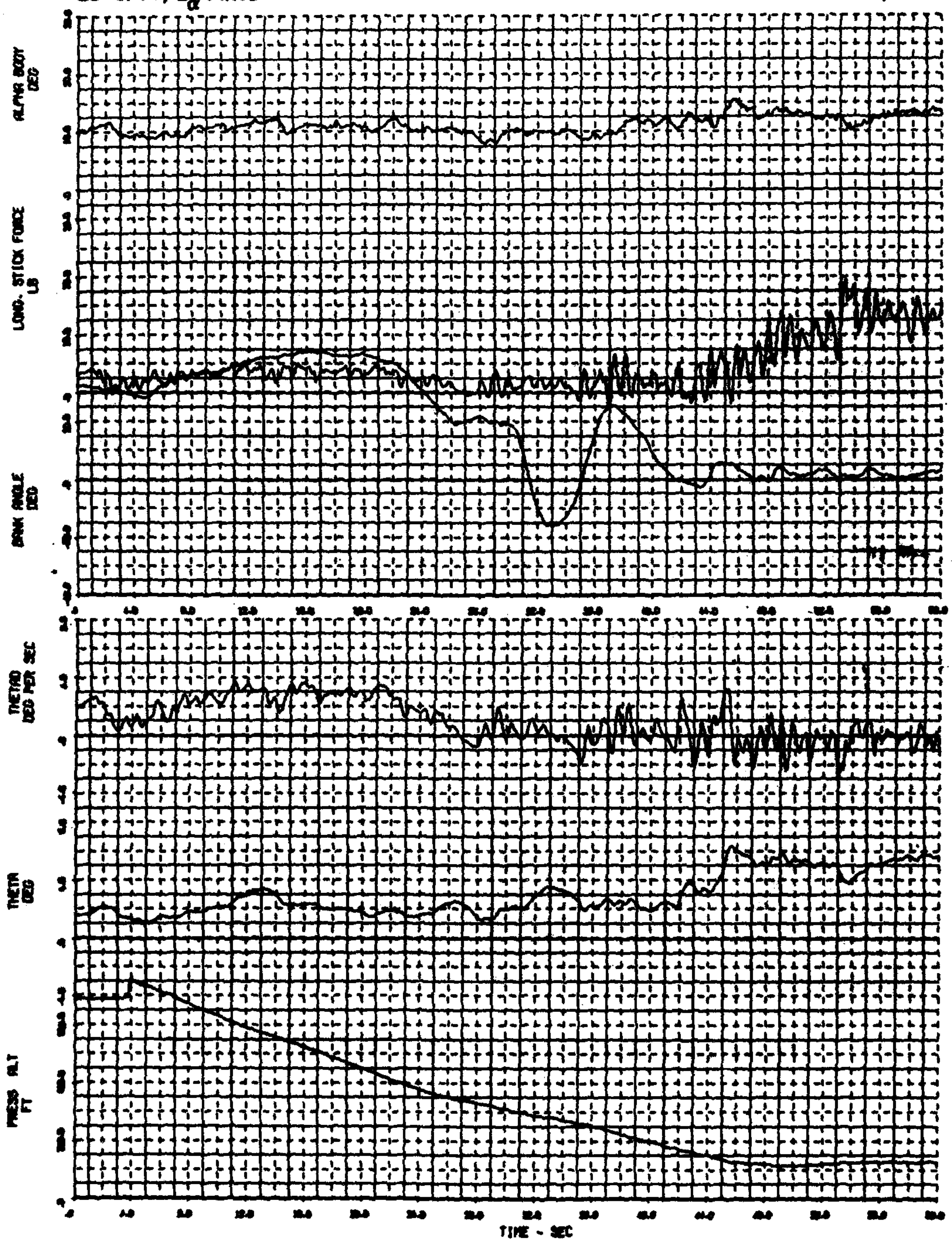
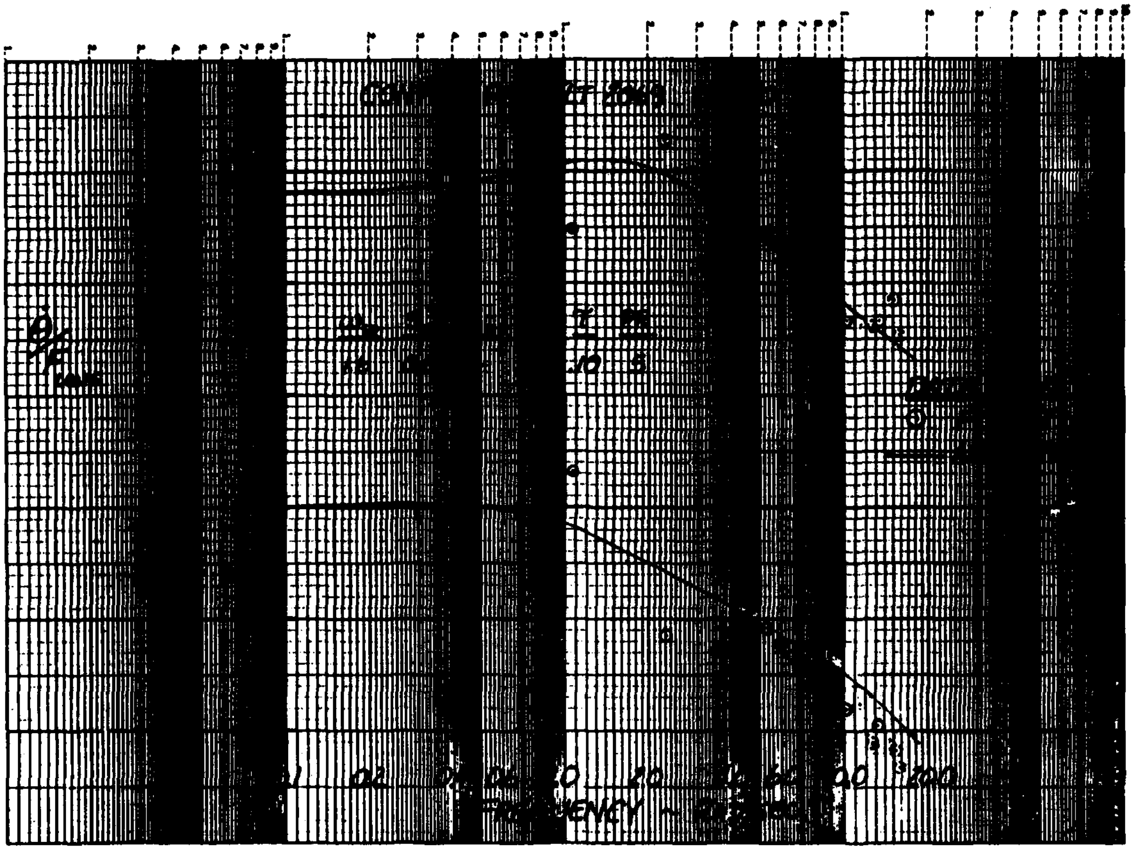


Figure E-6a. Flight Characteristics - Time History



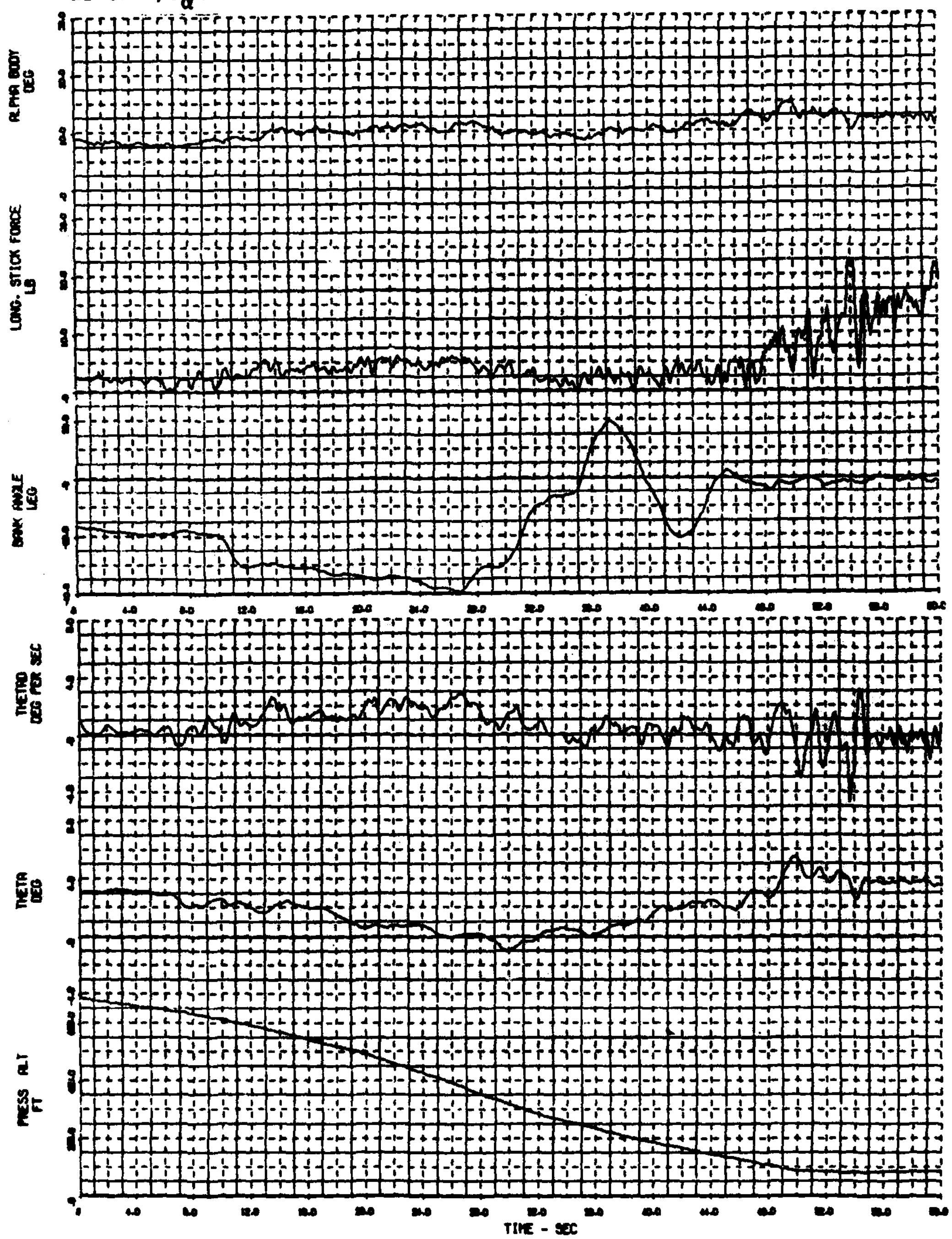
GP13-0004-00

Figure E-9b. Flight Characteristics - Pitch Rate Response

CONFIG P8 - LANDING NO. 2 FLT 2071 REC NO. 23

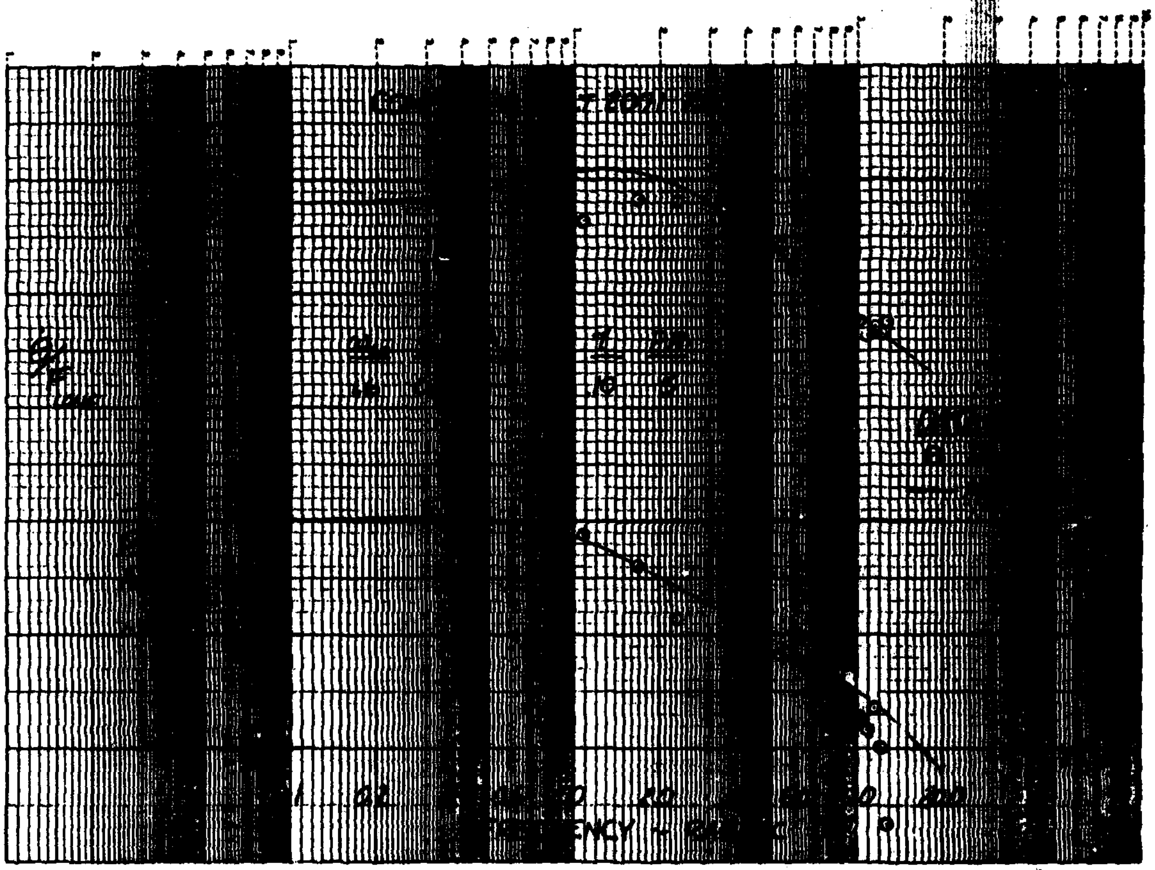
ES for P7, L_{α} Fixed

Pilot A; PR 5



GP13-0594-88

Figure E-10a. Flight Characteristics - Time History



GP13-0004-57

Figure E-10b. Flight Characteristics - Pitch Rate Response

CONFIG P9 -LANDING NO. 2 FLT 2069 REC NO. 11

ES for P7, L_α Free

Pilot A; PR 3

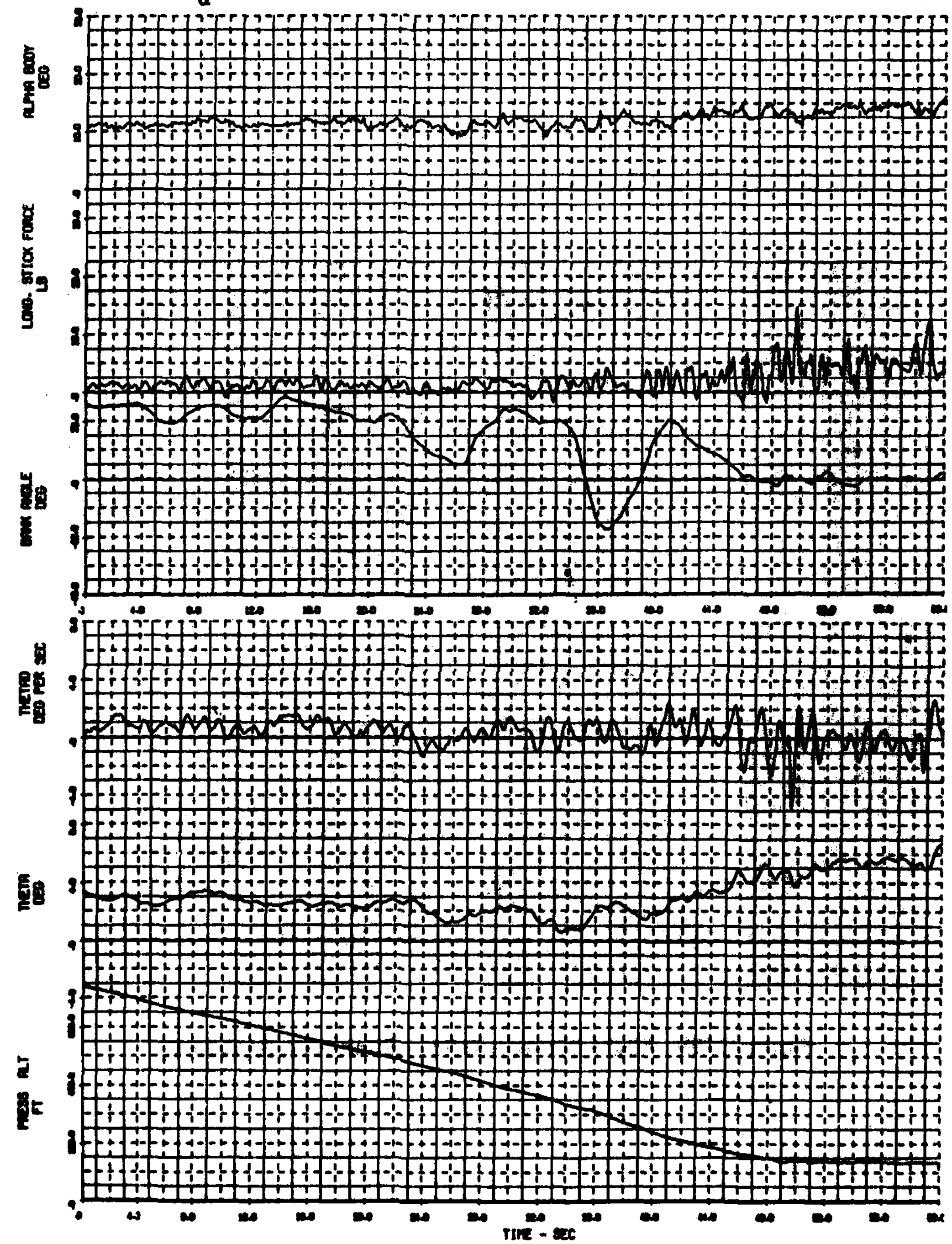


Figure E-11a. Flight Characteristics - Time History

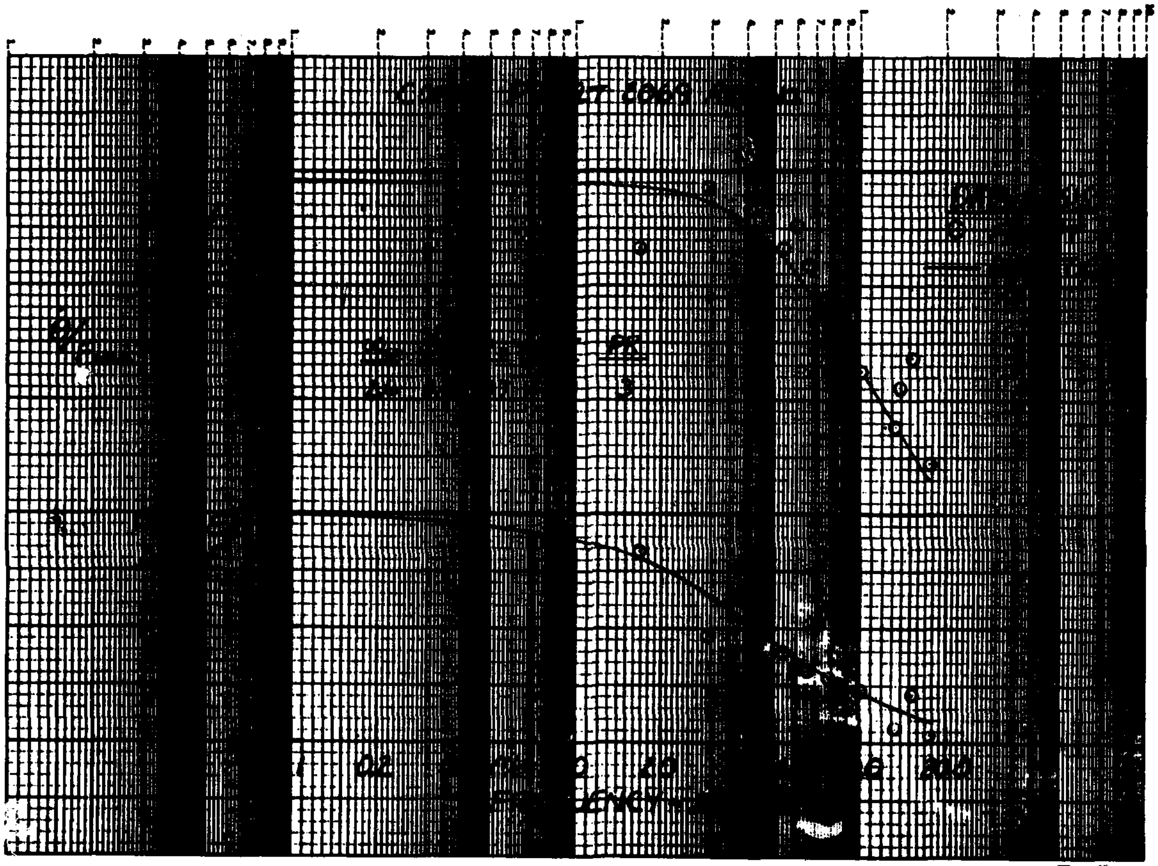
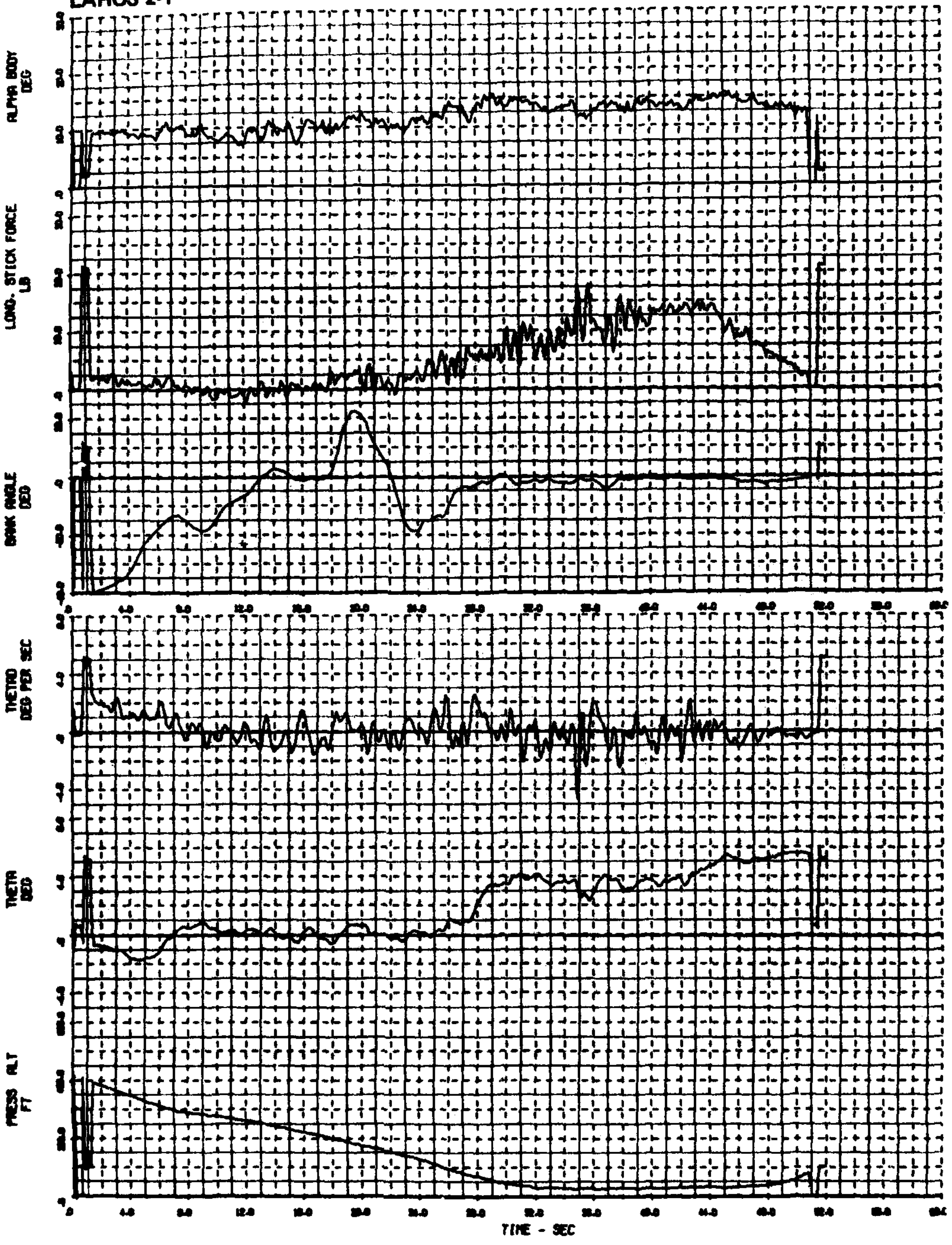


Figure E-11b. Flight Characteristics - Pitch Rate Response

CONFIG P10 - LANDING NO. 2 FLT 2062 REC NO. 4

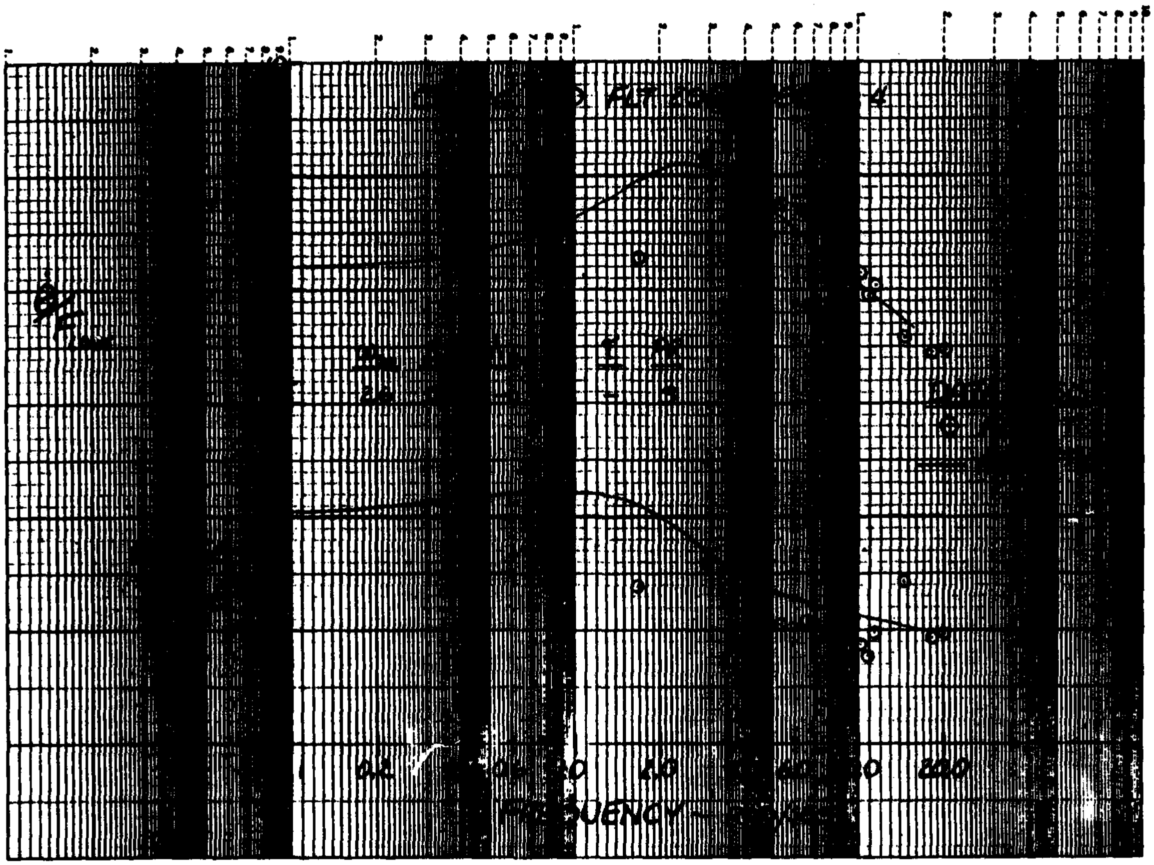
LAHOS 2-1

Pilot A; PR 3



GP13-0000-01

Figure E-12a. Flight Characteristics - Time History



GP13-0884-62

Figure E-12b. Flight Characteristics - Pitch Rate Response

CONFIG P10C - LANDING NO. 2 FLT 2072 REC NO. 20

P10 (LAHOS 2-1) Plus Time Delay (0.13 sec) Pilot A; PR 4

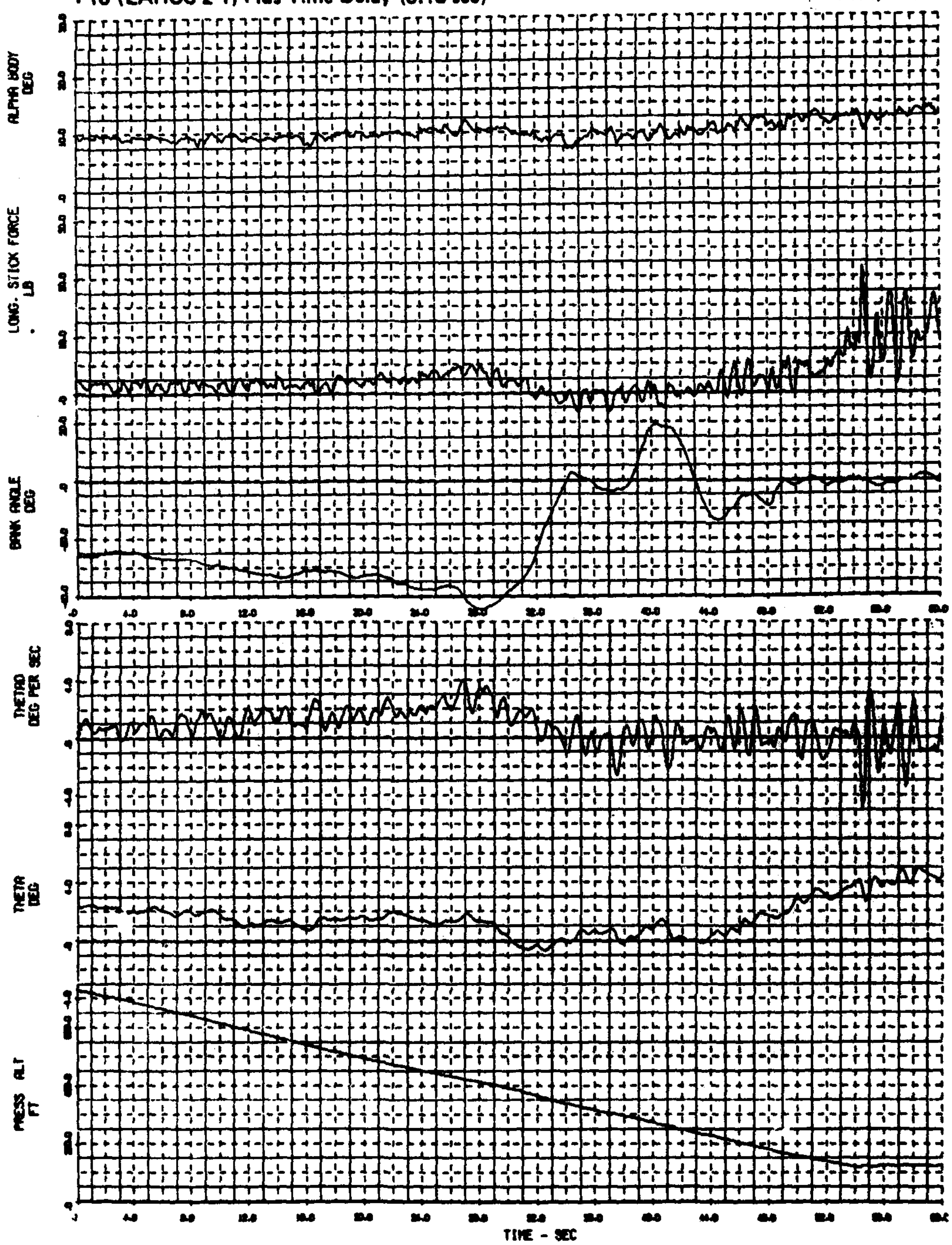
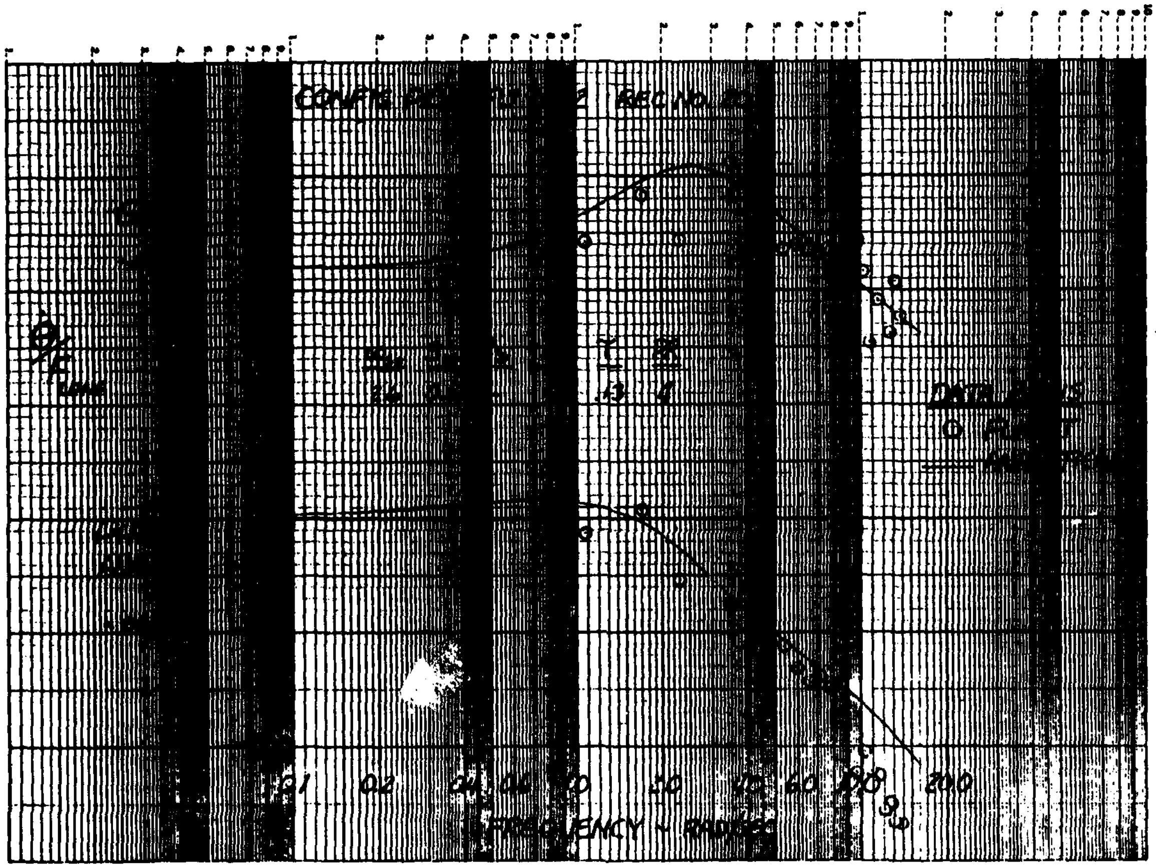


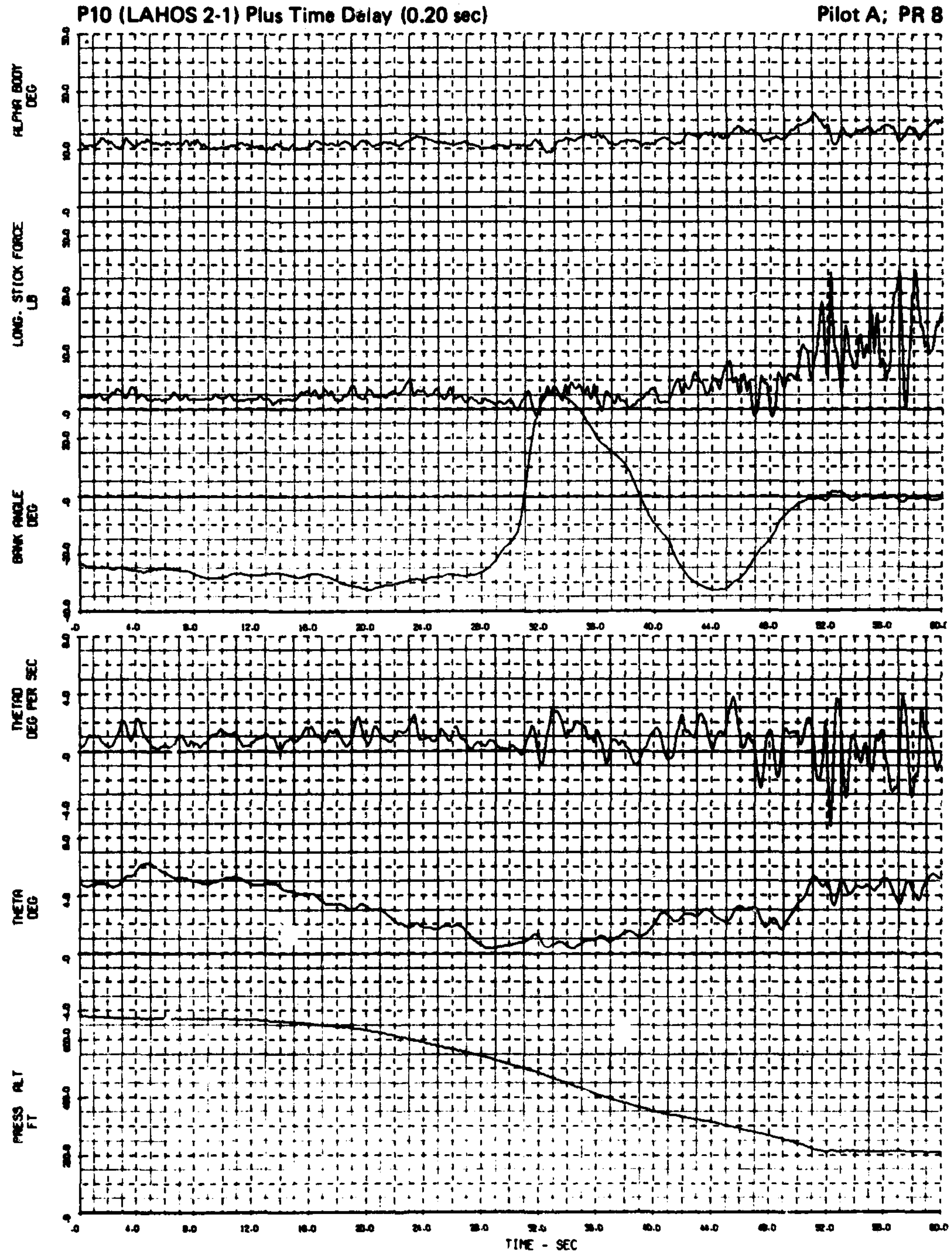
Figure E-13a. Flight Characteristics - Time History



GP13-0034-64

Figure E-13b. Flight Characteristics - Pitch Rate Response

CONFIG P 10D - LANDING NO. 2 FLT 2086 REC NO. 18

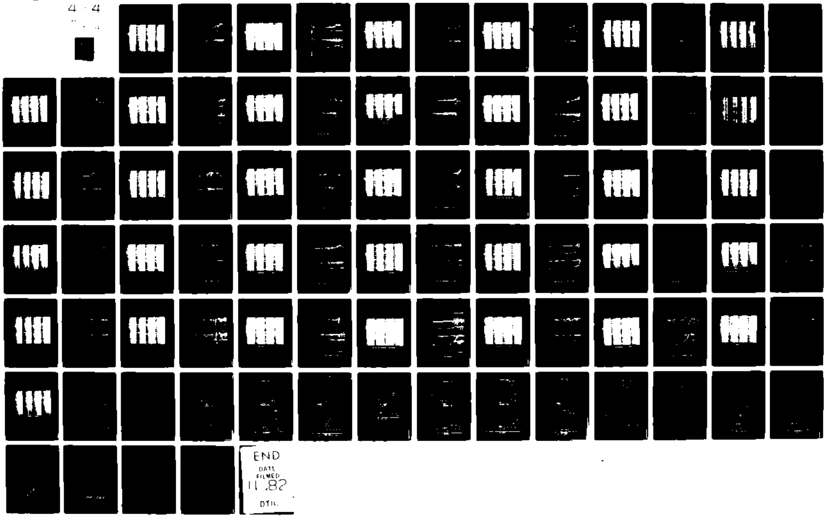


GP13-0824-66

Figure E-14a. Flight Characteristics - Time History

AD-A119 704 CALSPAN CORP BUFFALO NY FLIGHT RESEARCH DEPT F/G 1/2
EQUIVALENT SYSTEM VERIFICATION AND EVALUATION OF AUGMENTATION E--ETC(U)
SEP 81 R E SMITH, J HODGKINSON, R C SNYDER F33615-78-C-3602
UNCLASSIFIED CALSPAN-6241-F-3-VOL-2 AFWAL-TR-81-3116-VOL-2 NL

4 4



END
DATE FILMED
11 82
DTIC

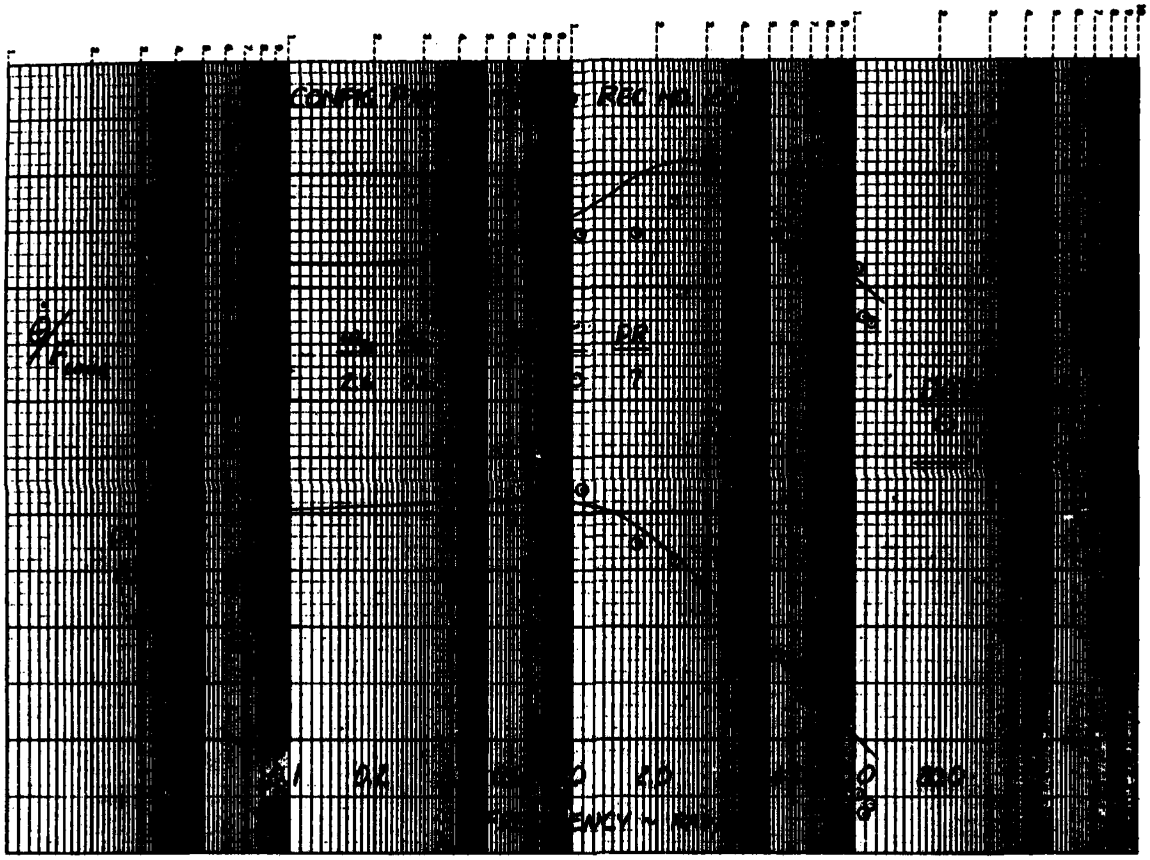


Figure E-14b. Flight Characteristics - Pitch Rate Response

CONFIG P10D -LANDING NO. 2 FLT 2070 REC NO. 18

P10 (LAHOS 2-1) Plus Time Delay (0.20 sec) **Pilot B; PR 8**

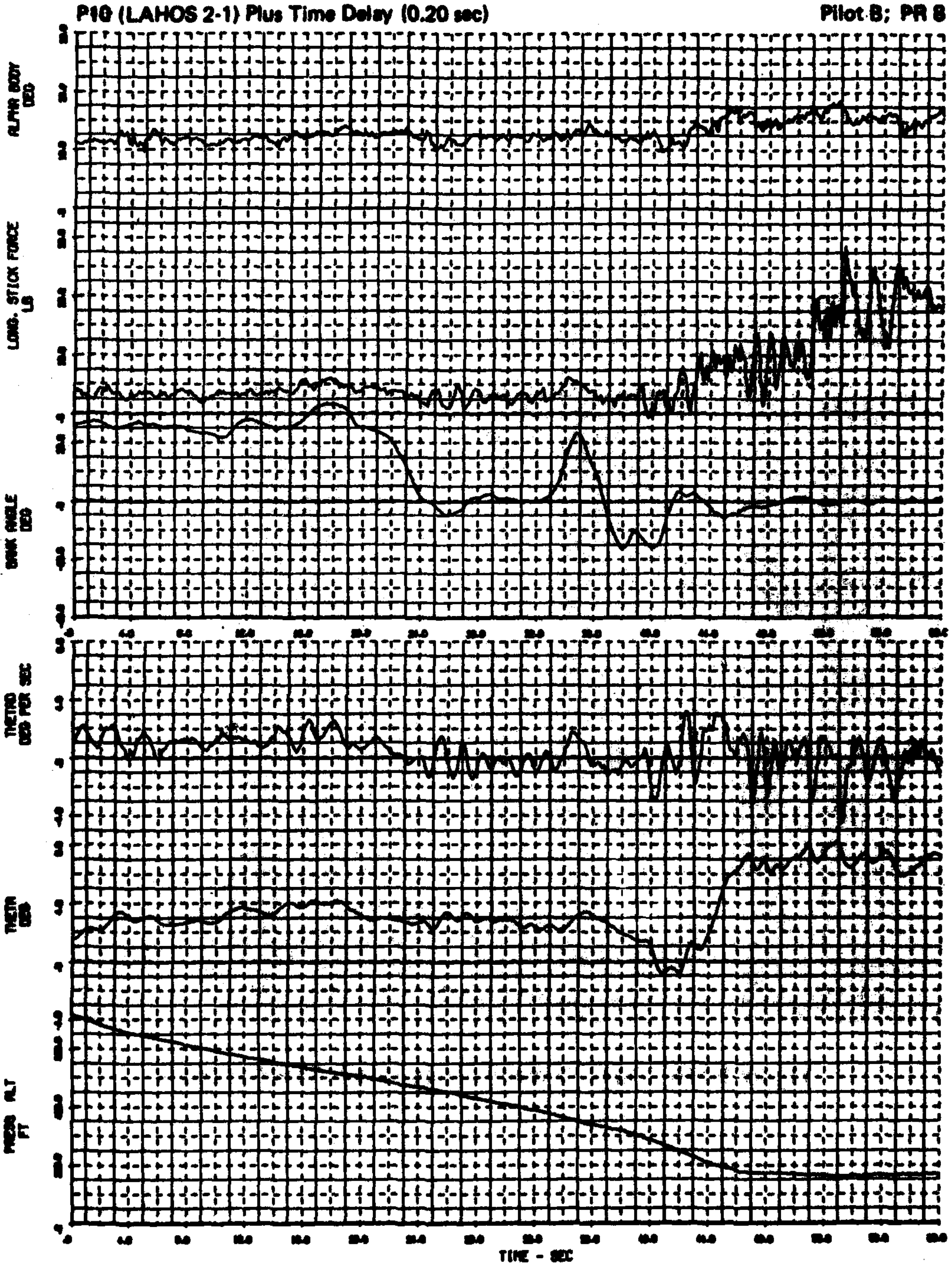
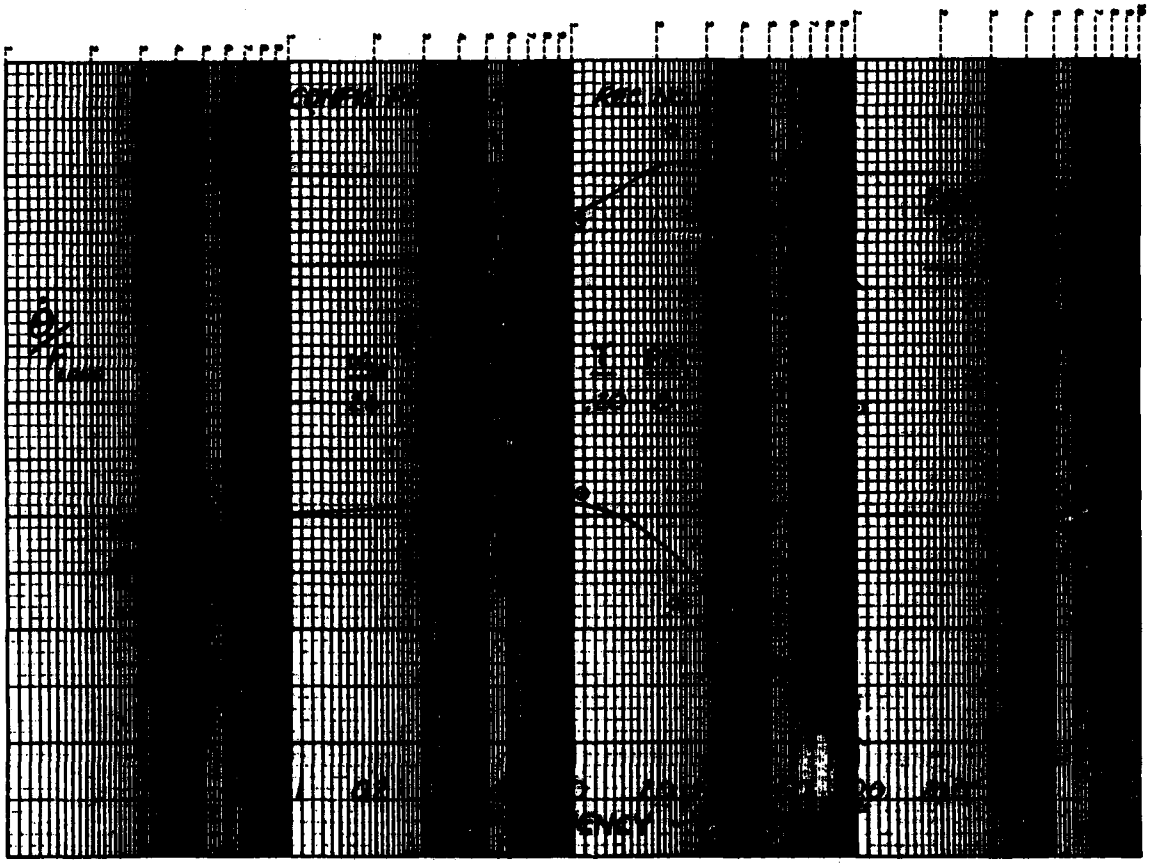


Figure E-15a. Flight Characteristics - Time History



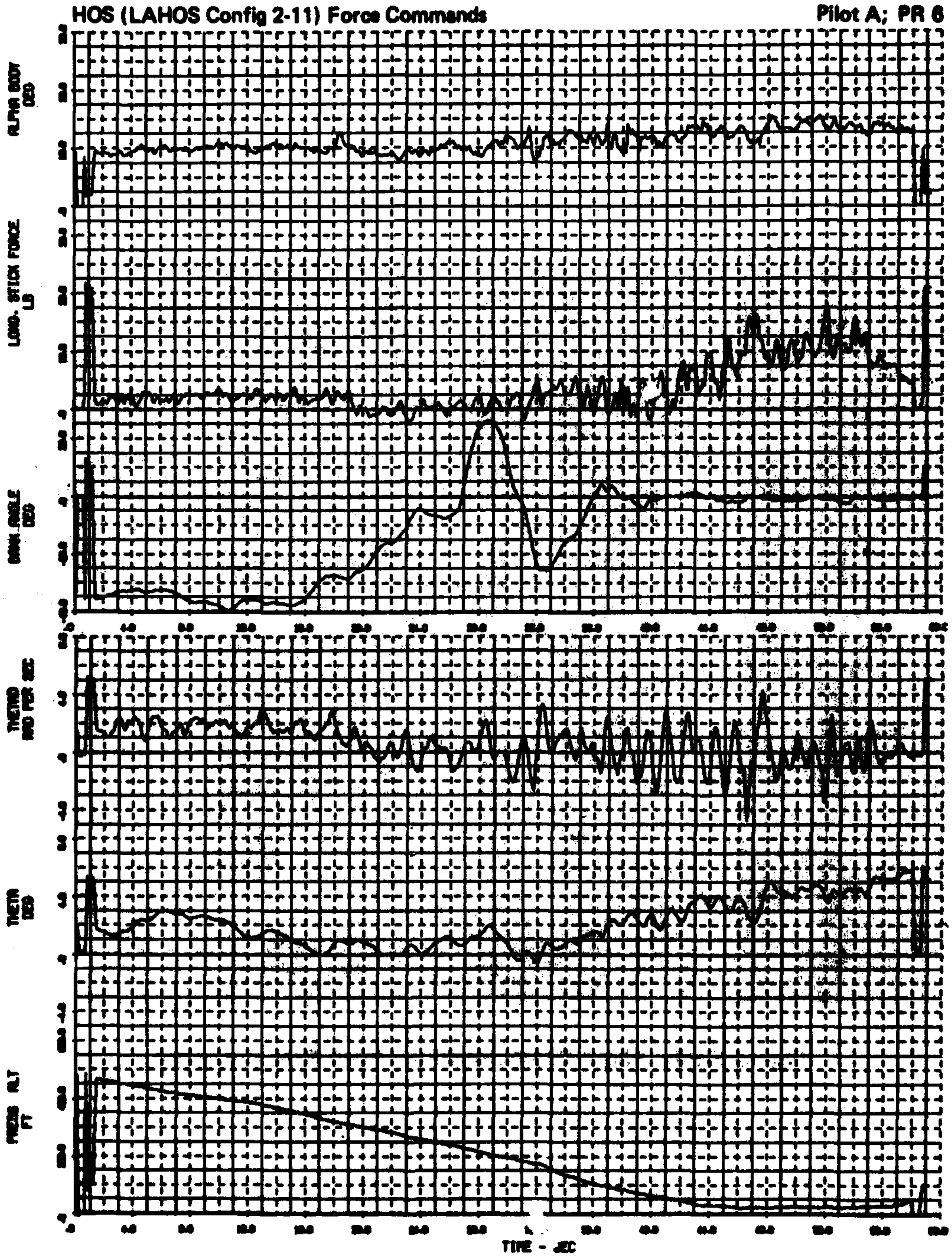
GP13-0884-68

Figure E-15b. Flight Characteristics - Pitch Rate Response

CONFIG P11 - LANDING NO. 2 FLT 2062 REC NO. 7

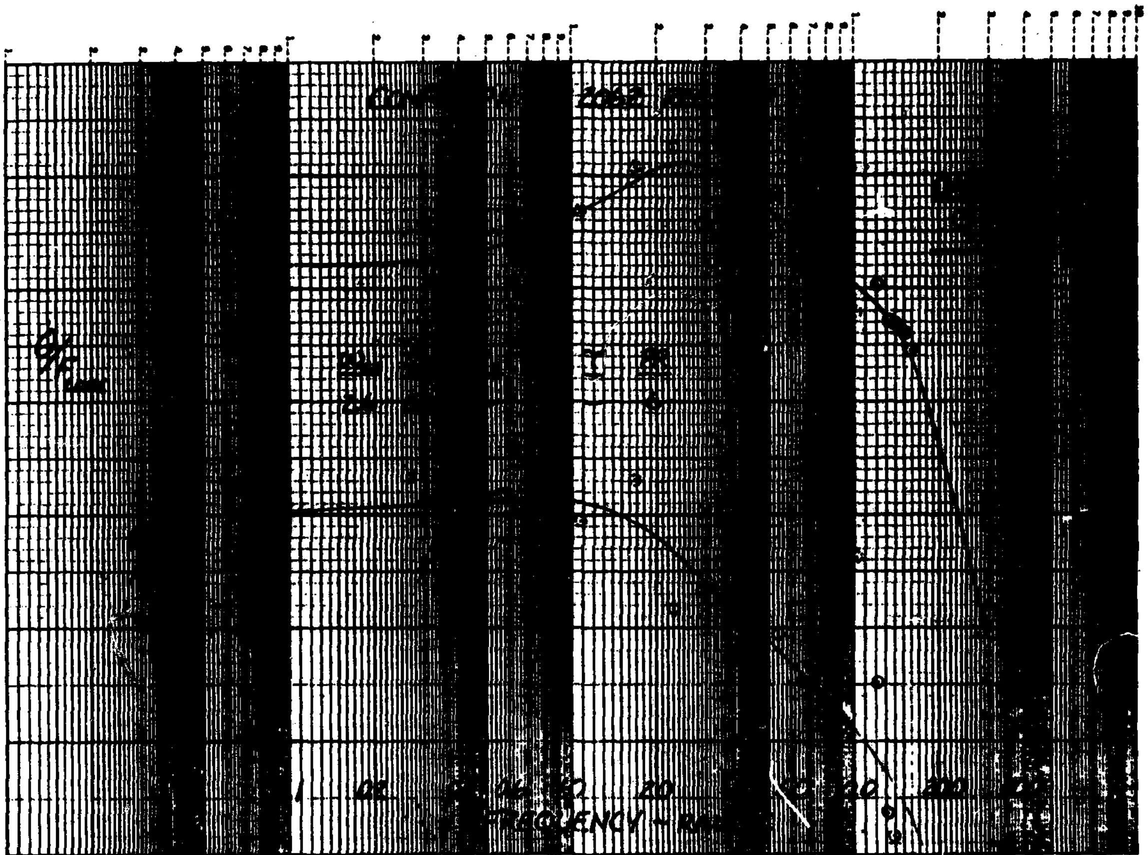
HOS (LAHOS Config 2-11) Force Commands

Pilot A; PR 6



GP10000000

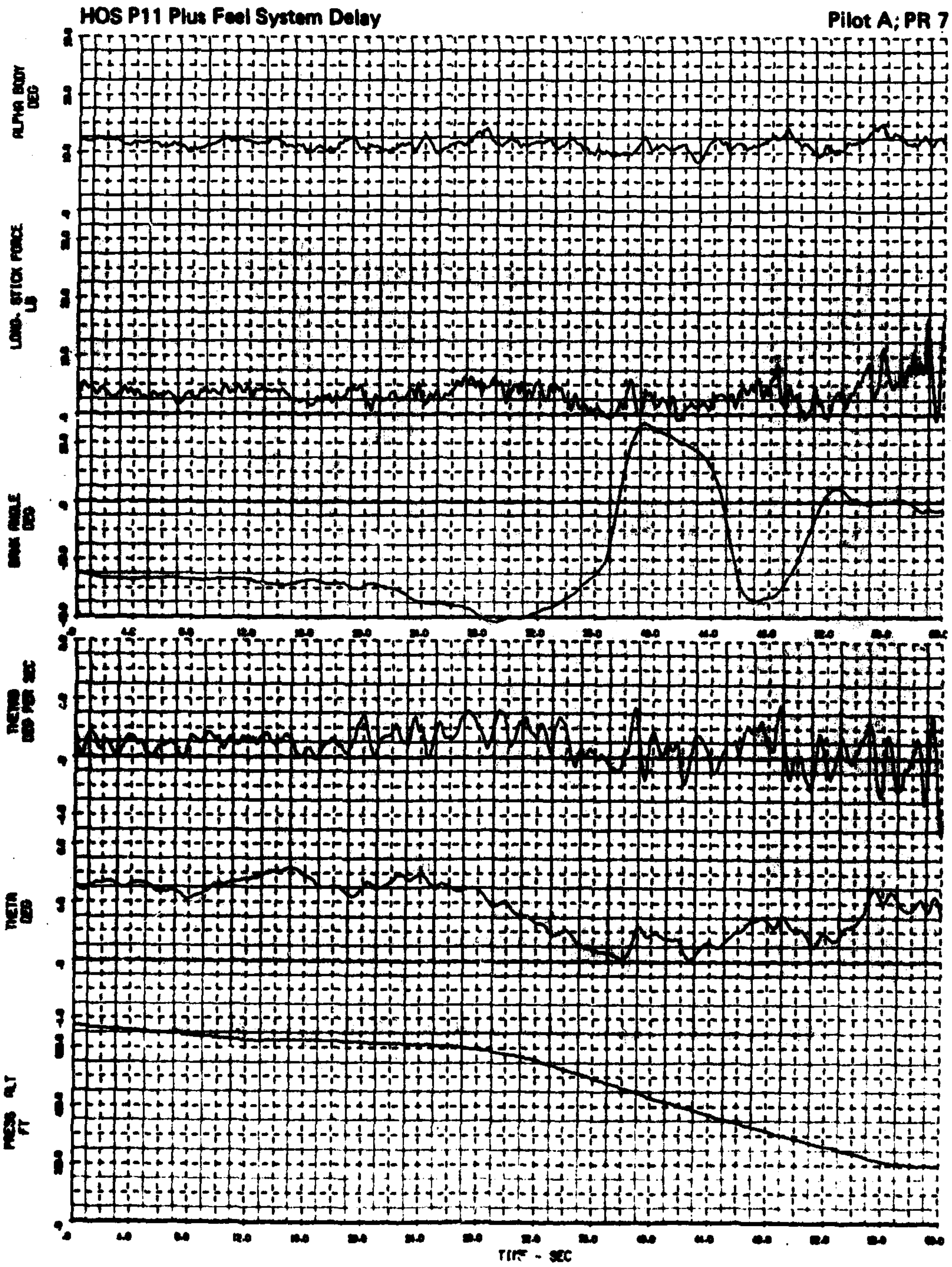
Figure E-16a. Flight Characteristics - Time History



GP13-0024-70

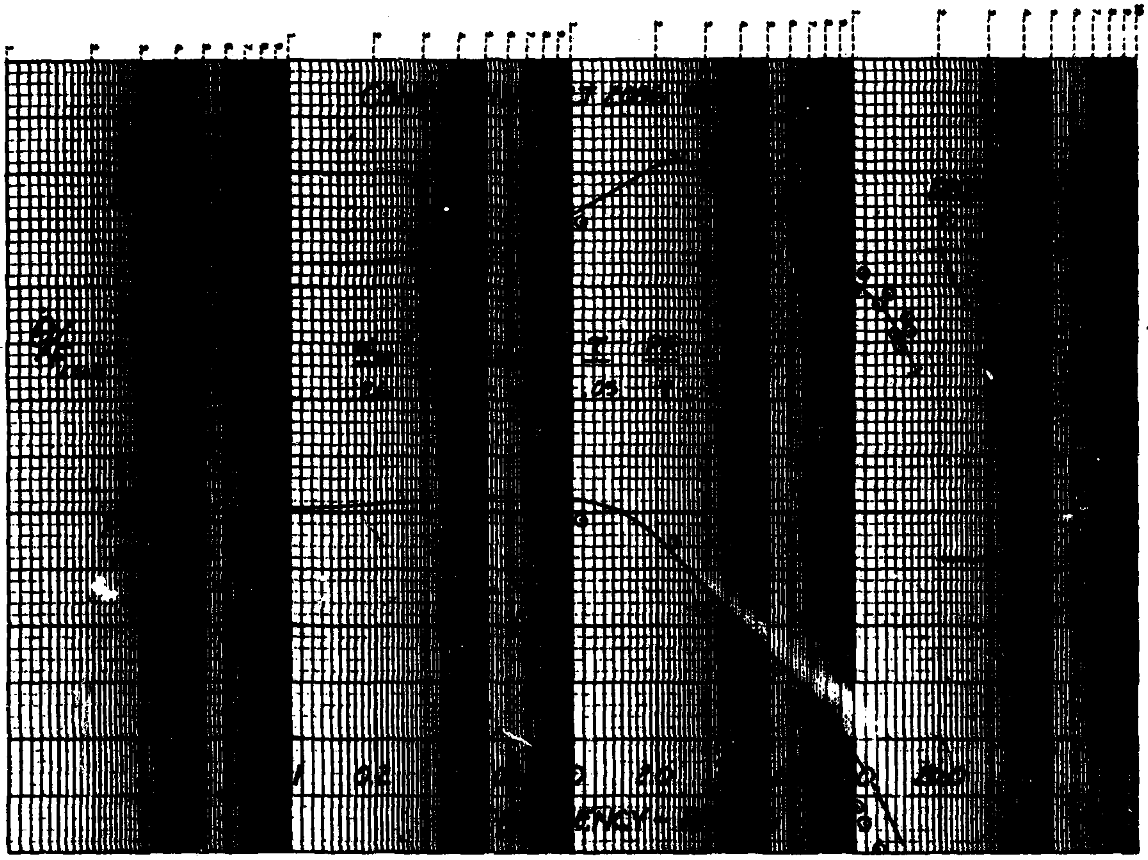
Figure E-16b. Flight Characteristics - Pitch Rate Response

CONFIG P11A - LANDING NO. 2 FLT 2086 REC NO. 9



GP13-0224-71

Figure E-17a. Flight Characteristics - Time History



GP13-0094-72

Figure E-17b. Flight Characteristics - Pitch Rate Response

CONFIG P12 - LANDING NO. 1 FLT 2062 REC NO. 12

ES for P11, L_α Fixed

Pilot A; PR 7

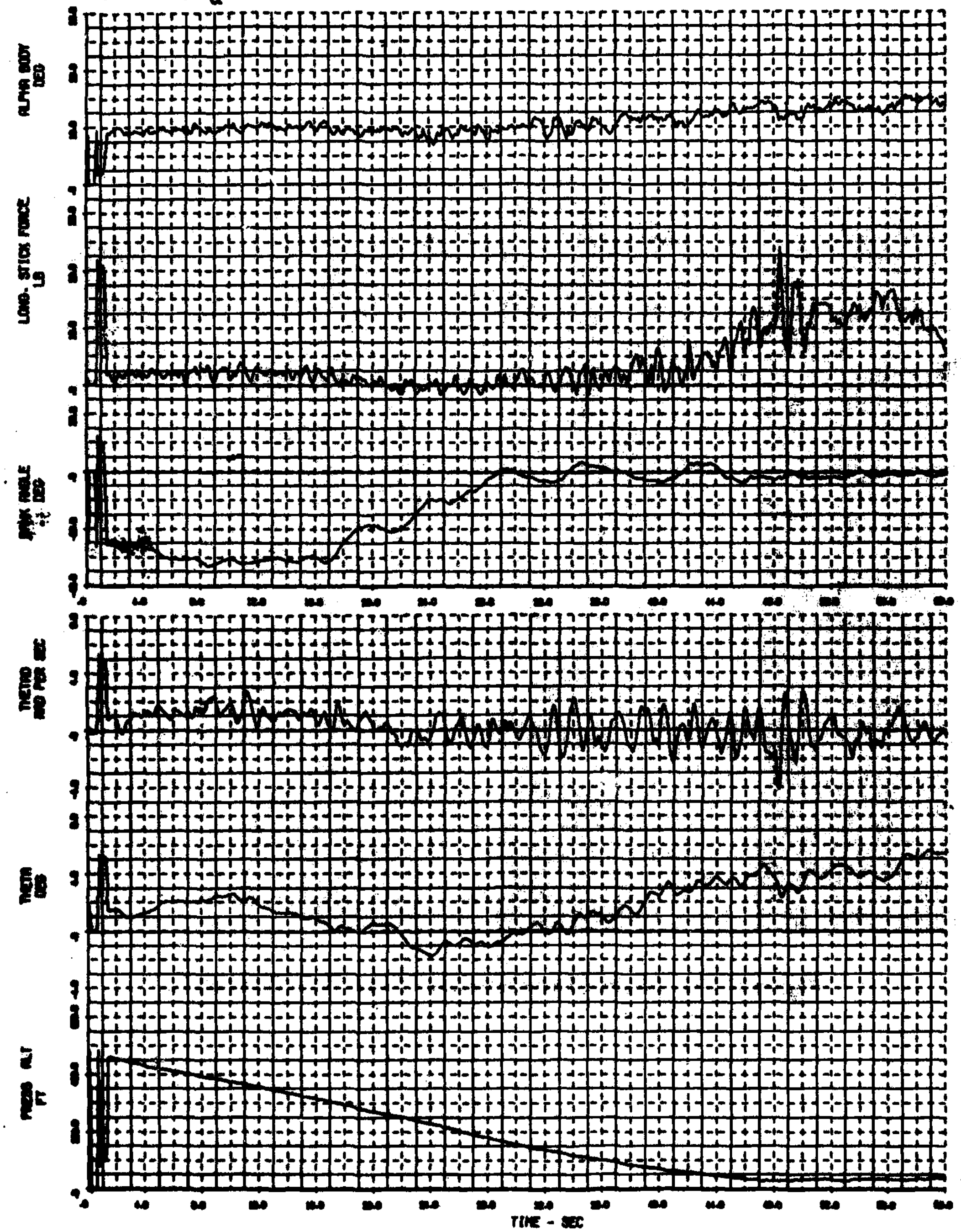
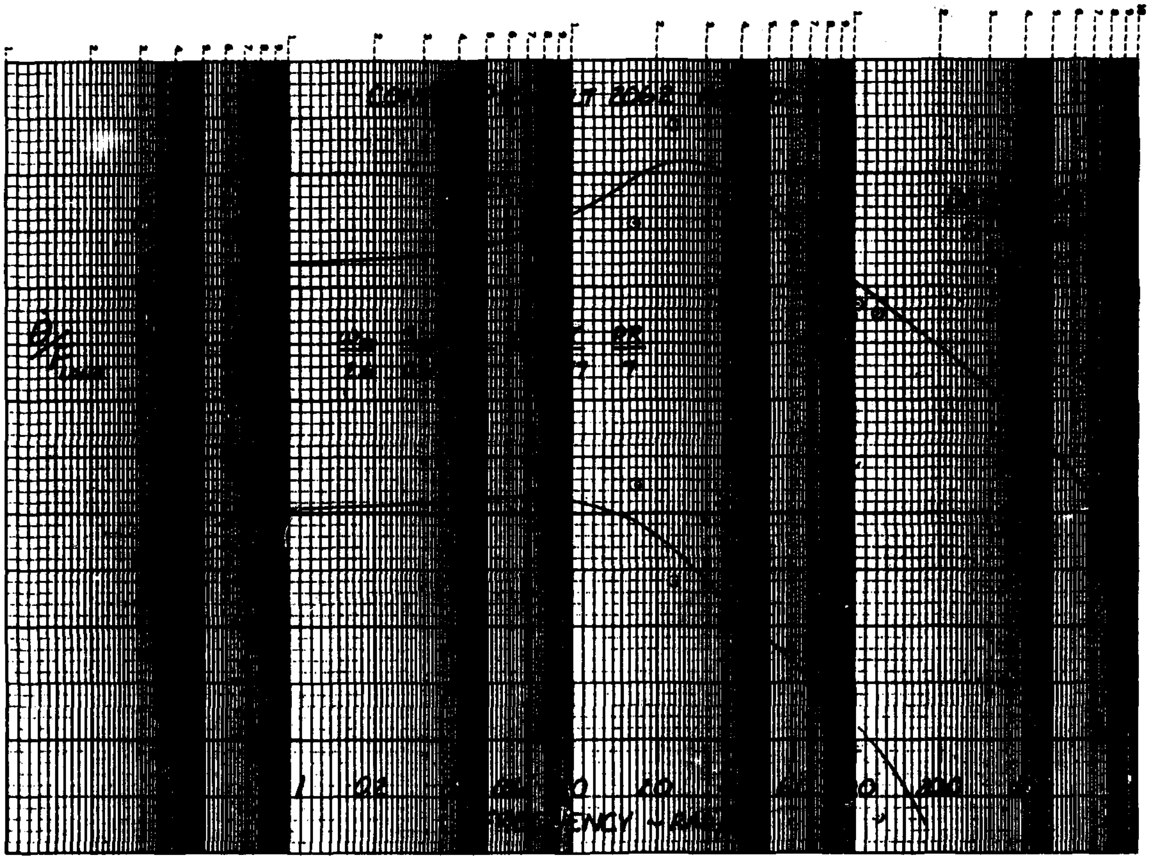


Figure E-18a. Flight Characteristics - Time History



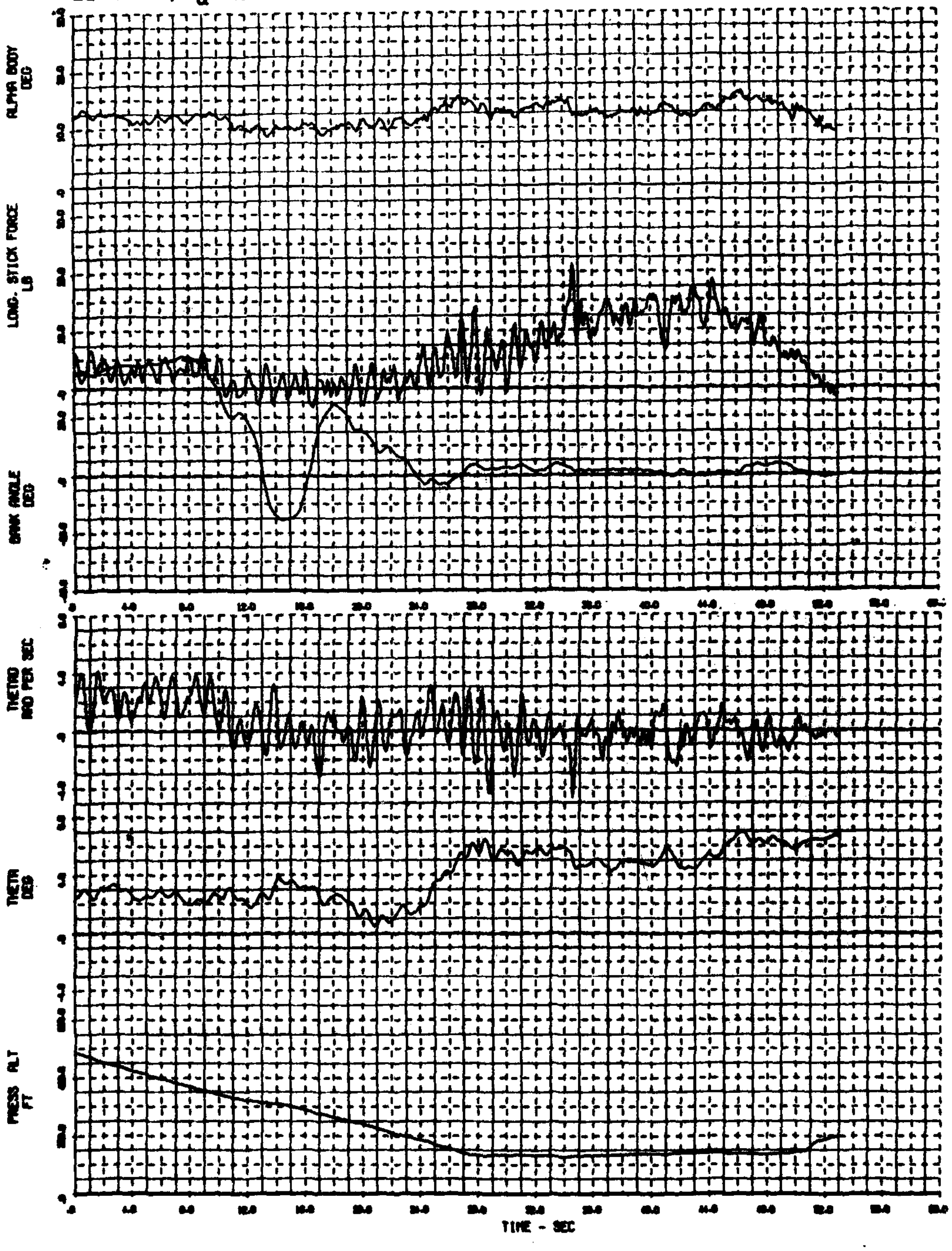
GP13-0824-74

Figure E-18b. Flight Characteristics - Pitch Rate Response

CONFIG P12 - LANDING NO. 2 FLT 2069 REC NO. 3

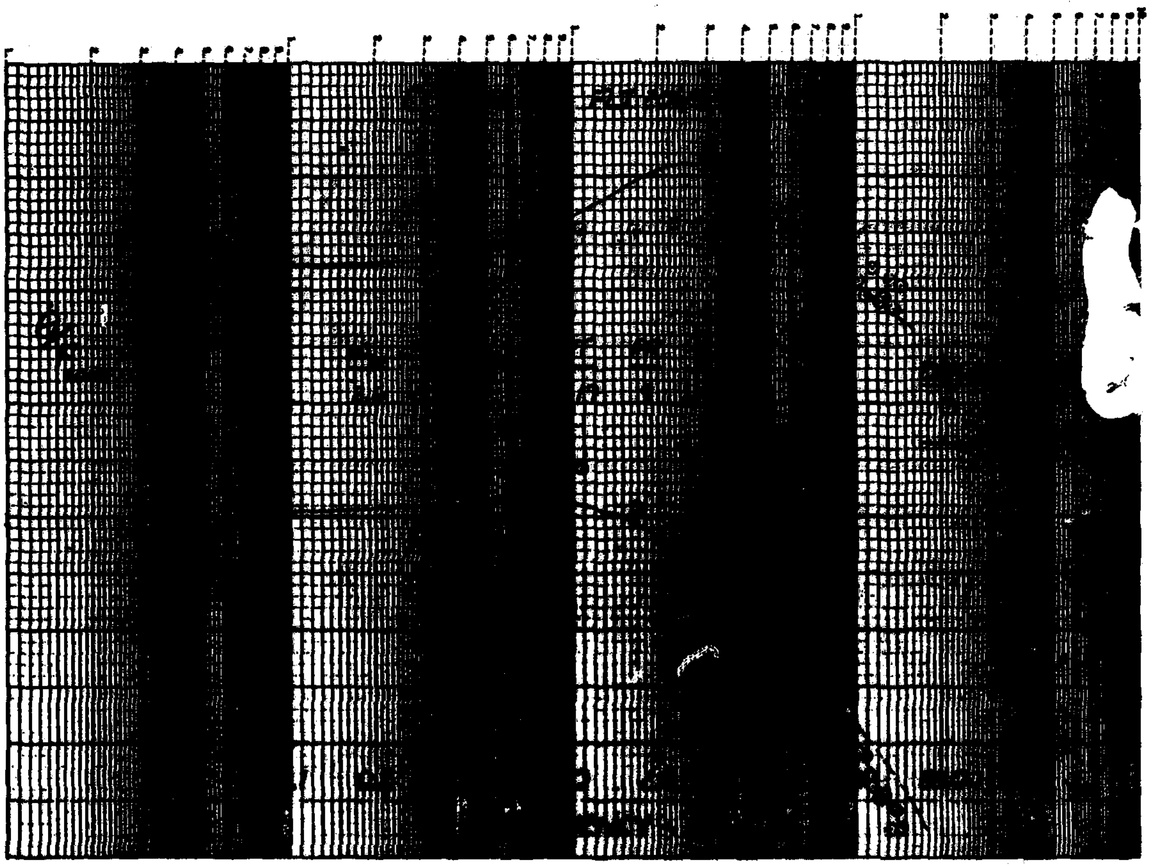
ES for P11, L_α Fixed

Pilot A; PR 9



GP13-0324-75

Figure E-19a. Flight Characteristics - Time History



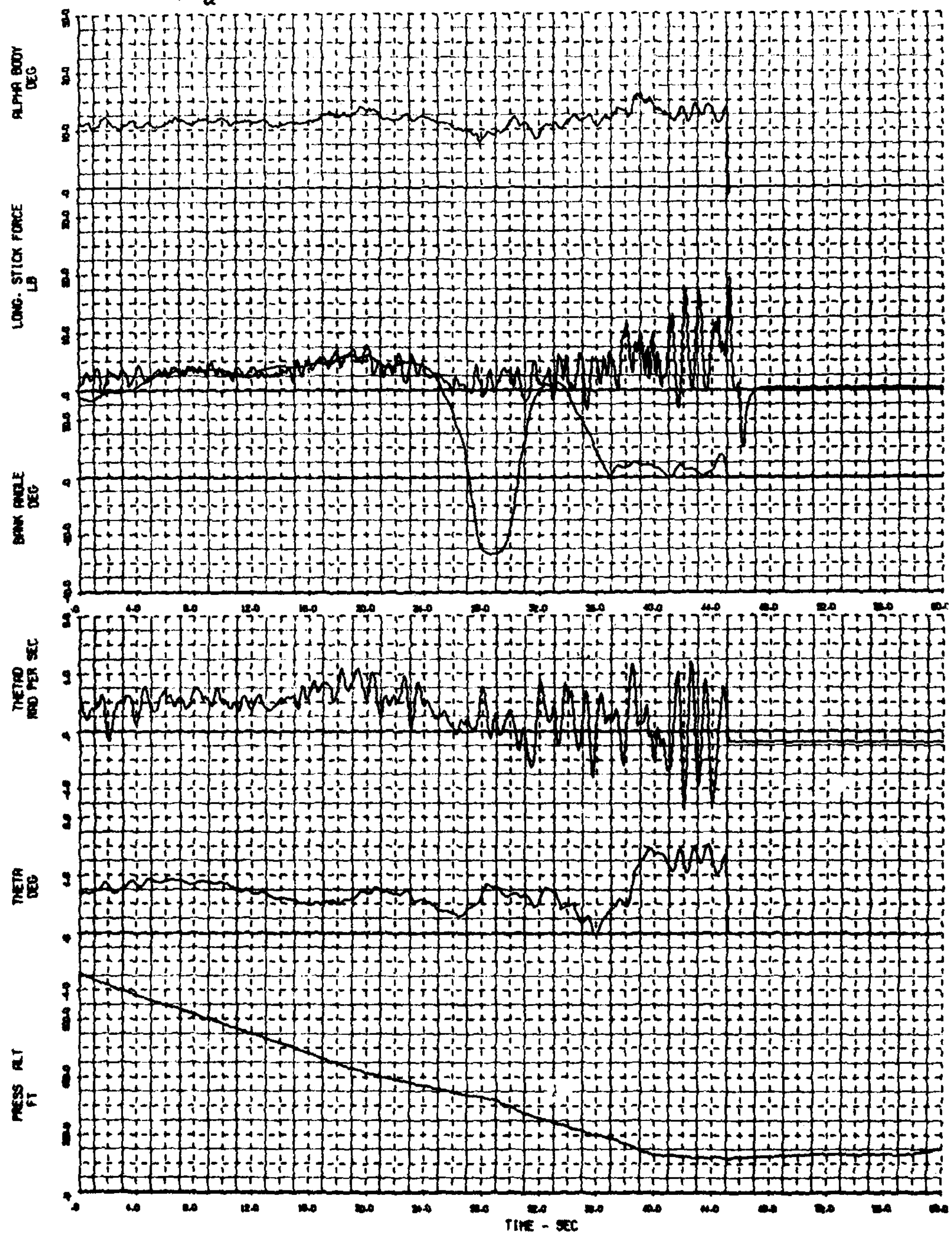
GP13-0384-78

Figure E-19b. Flight Characteristics - Pitch Rate Response

CONFIG P12 - LANDING NO. 3 FLT 2069 REC NO. 4

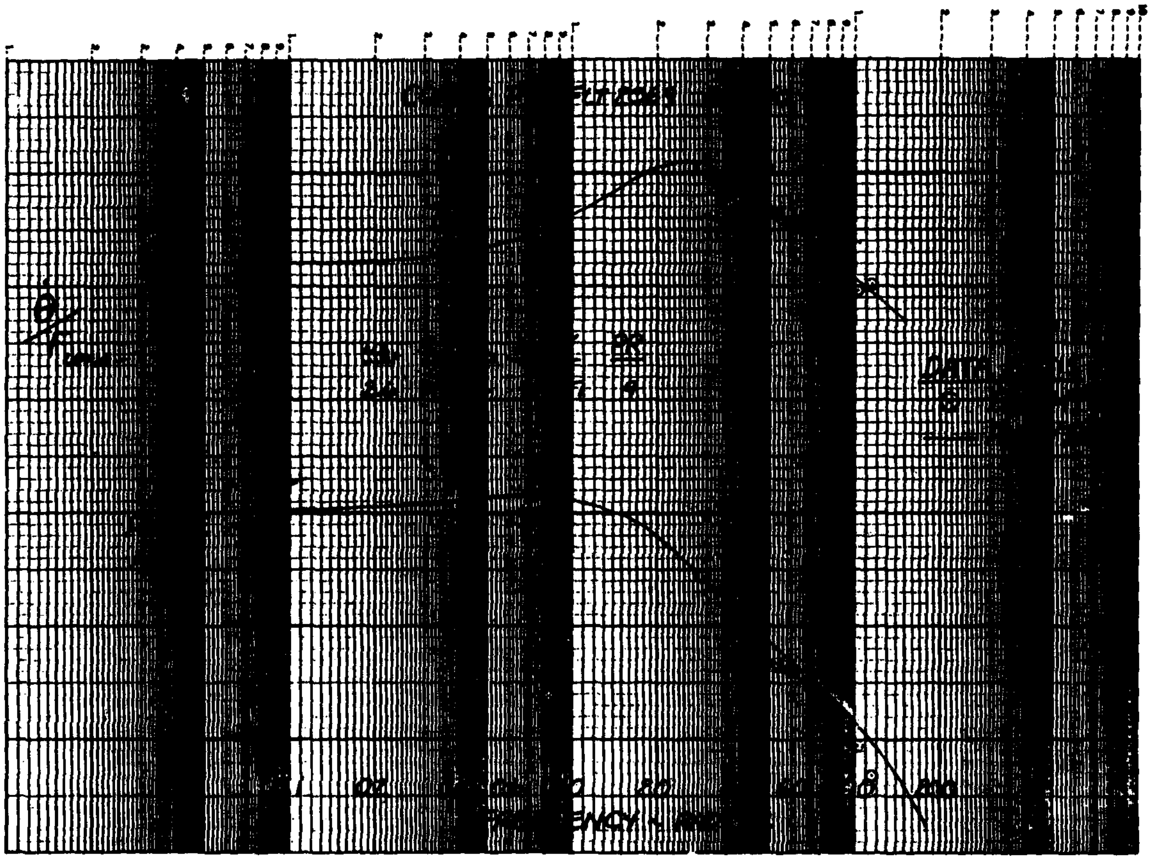
ES *for* P11, L_α Fixed

Pilot A; PR 9



GP13-0284-77

Figure E-20a. Flight Characteristics - Time History



GP13-0224-78

Figure E-20b. Flight Characteristics - Pitch Rate Response

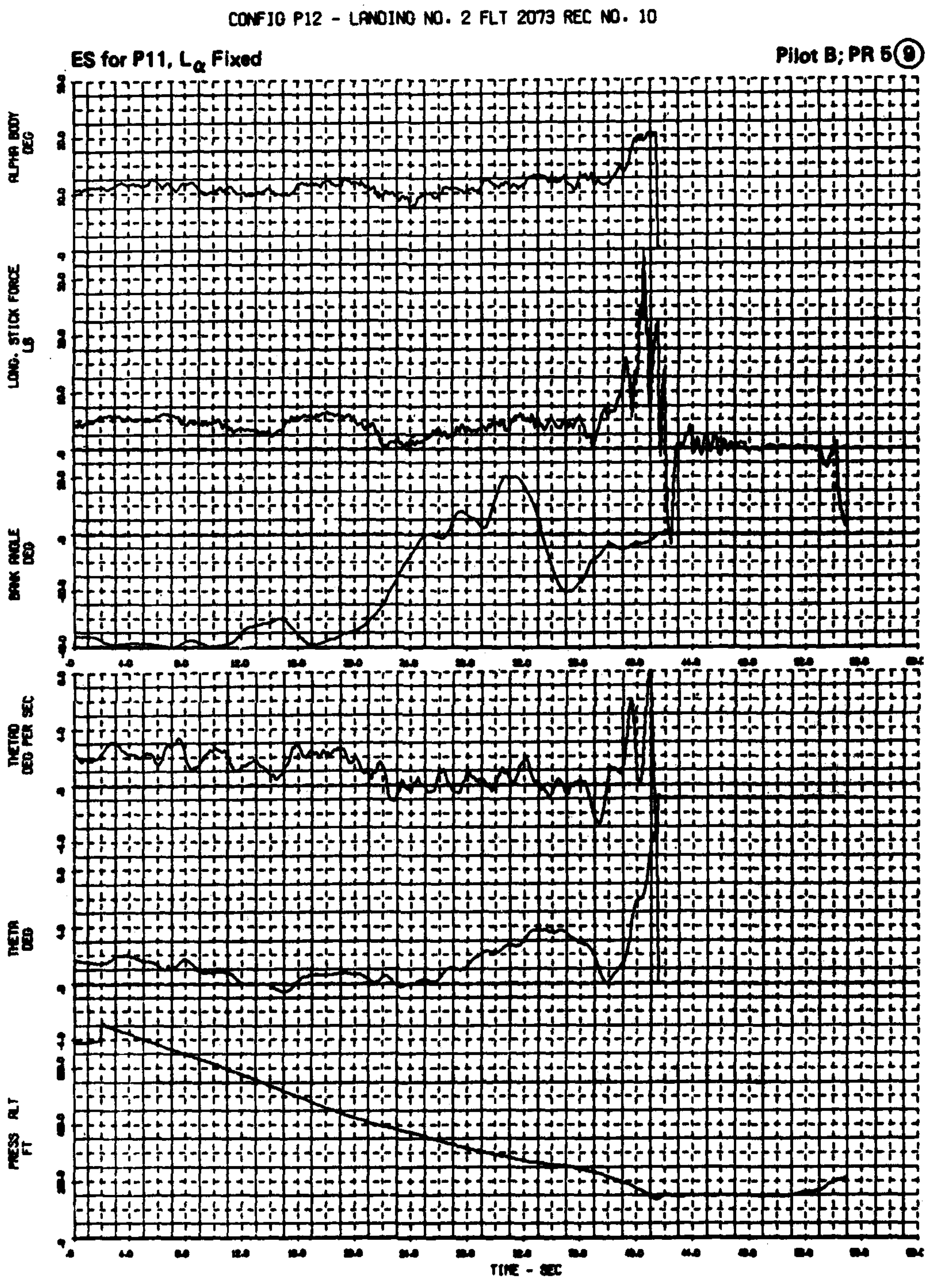


Figure E-21a. Flight Characteristics - Time History

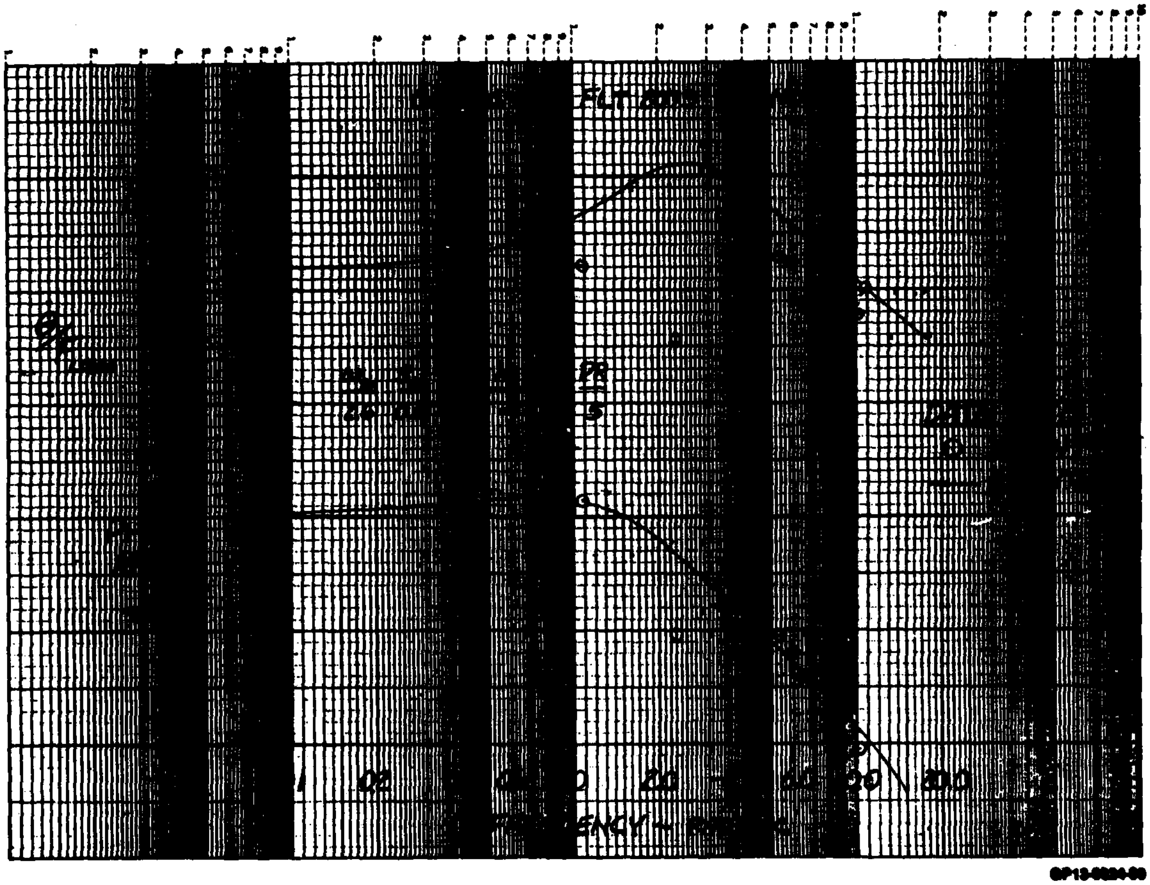
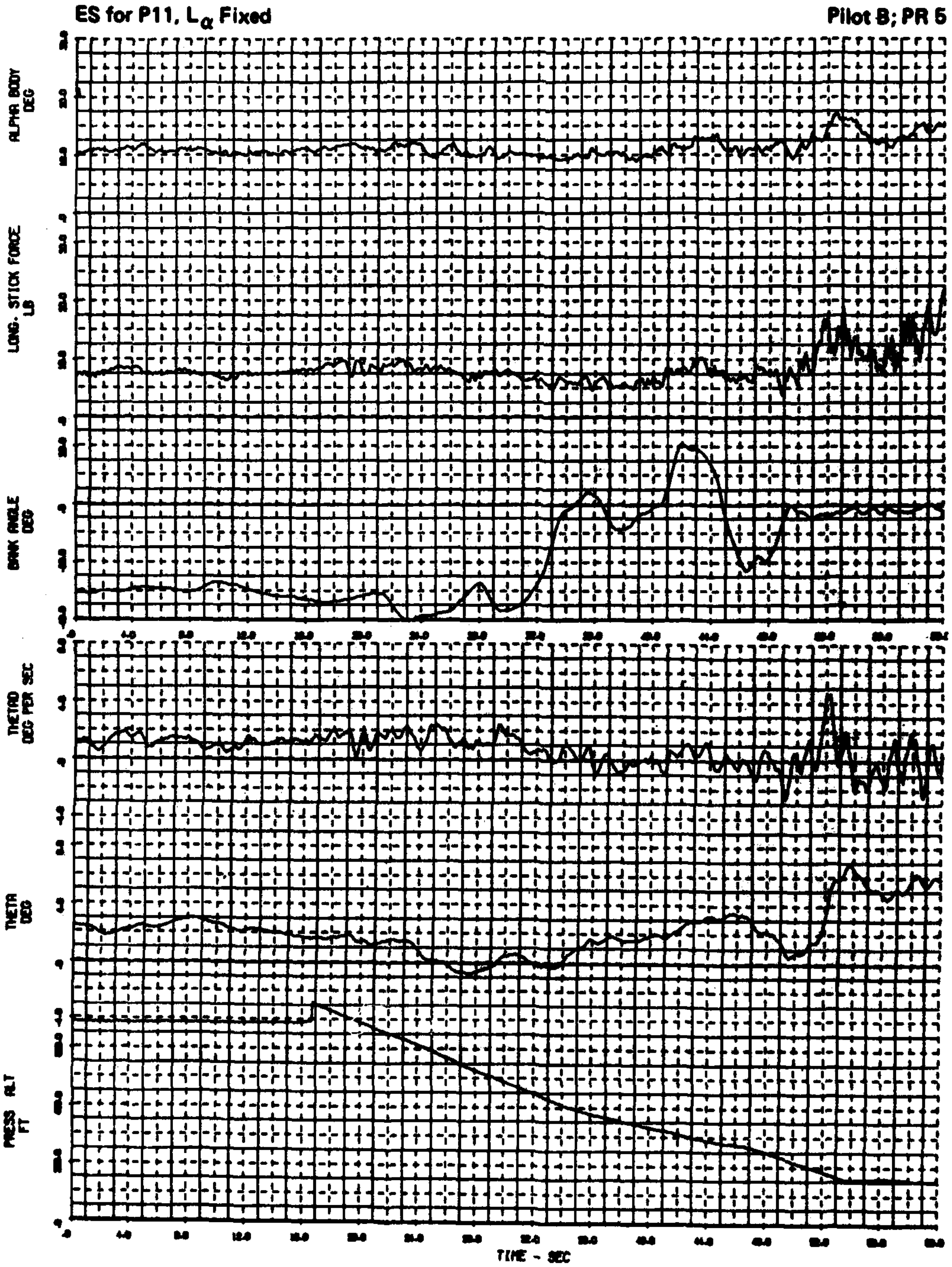


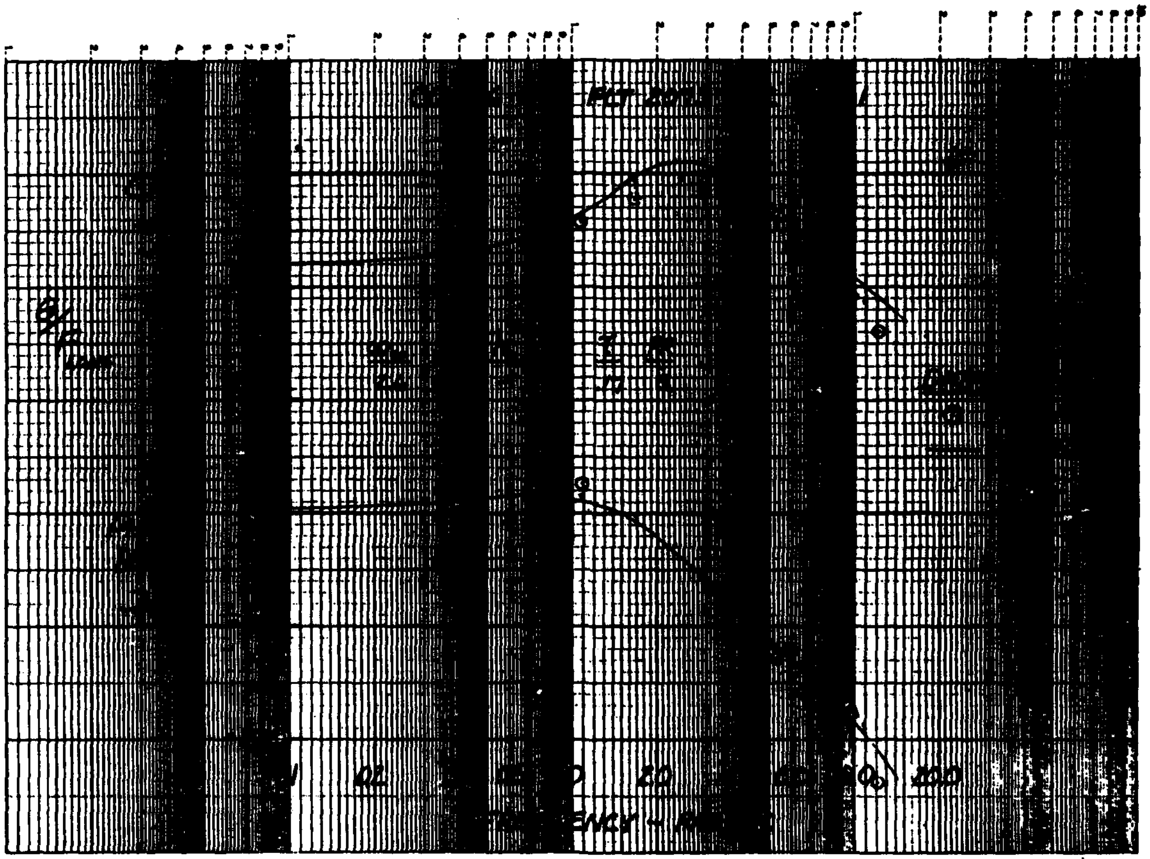
Figure E-21b. Flight Characteristics - Pitch Rate Response

CONFIG P12 - LANDING NO. 2 FLT 2073 REC NO. 11



GP13-0284-01

Figure E-22a. Flight Characteristics - Time History



GP93-0324-92

Figure E-22b. Flight Characteristics - Pitch Rate Response

CONFIG P12A - LANDING NO. 1 FLT 2069 REC NO. 15

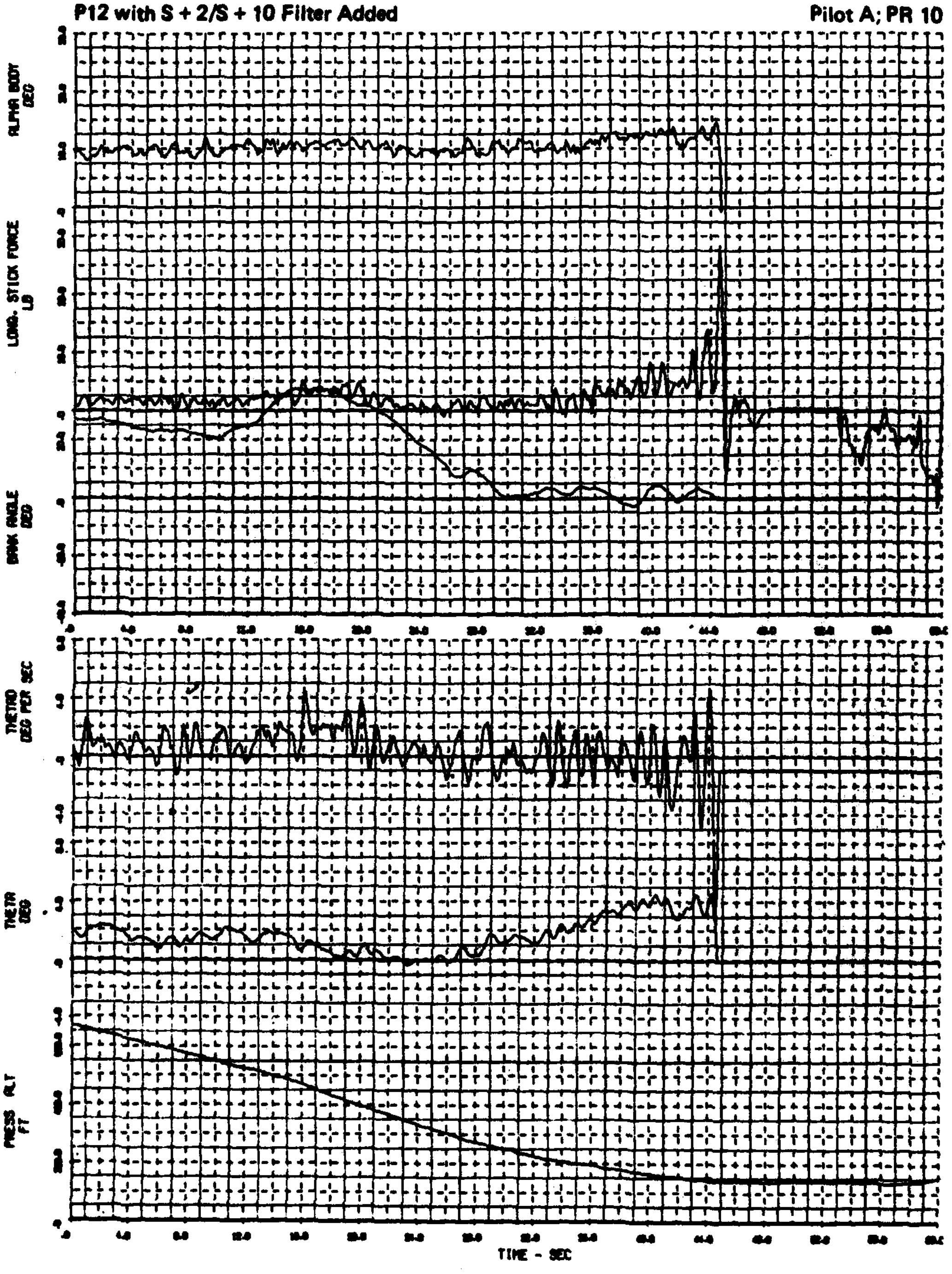
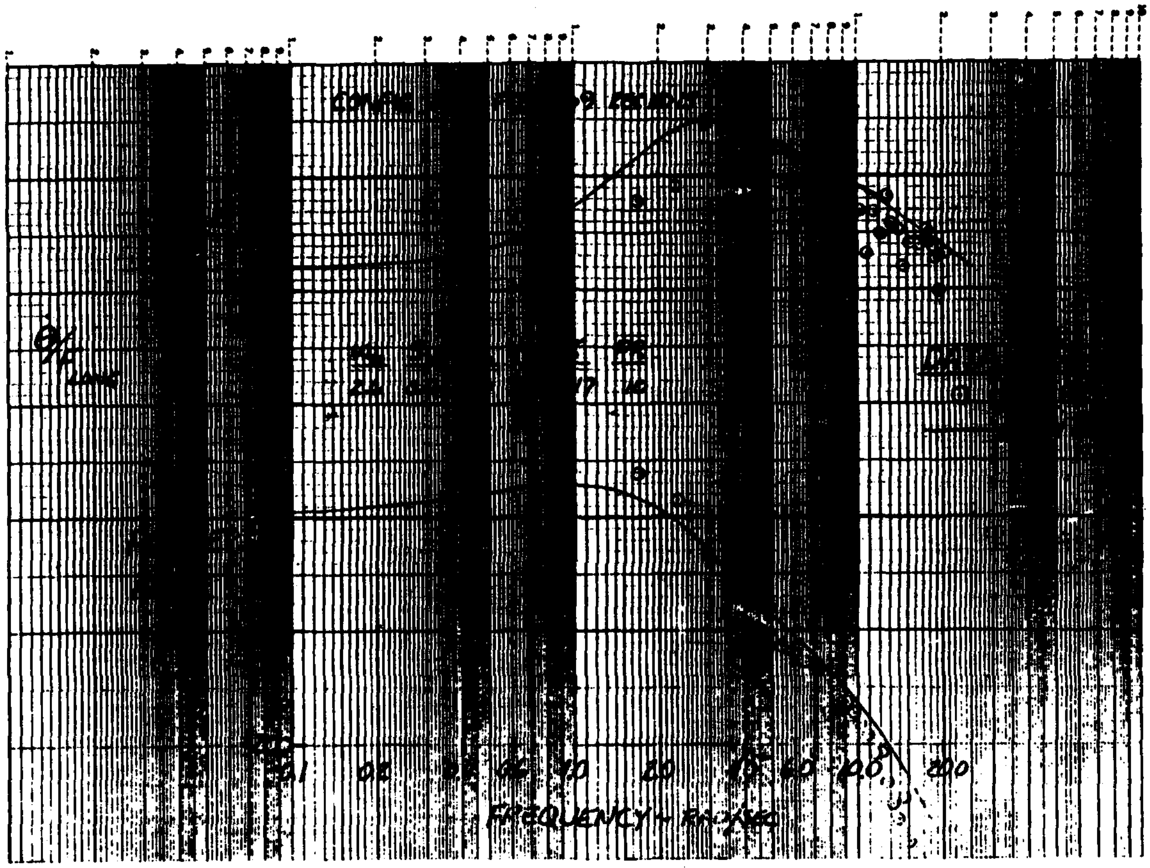


Figure E-23a. Flight Characteristics - Time History



GP13-0824-64

Figure E-23b. Flight Characteristics - Pitch Rate Response

CONFIG P12B - LANDING NO. 2 FLT 2072 REC NO. 25

P12 with S + 10/S + 20 Filter Added

Pilot A; PR 9

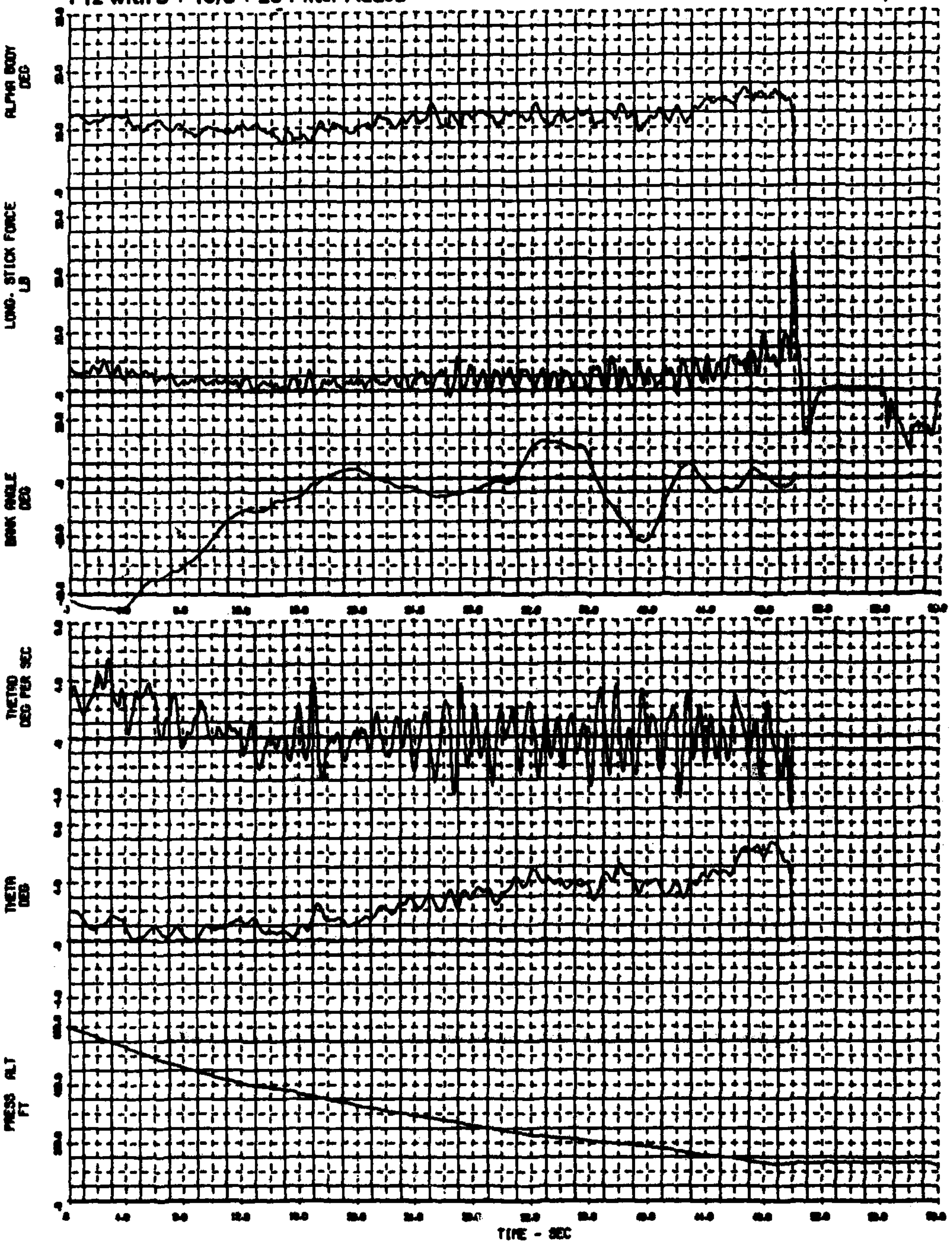
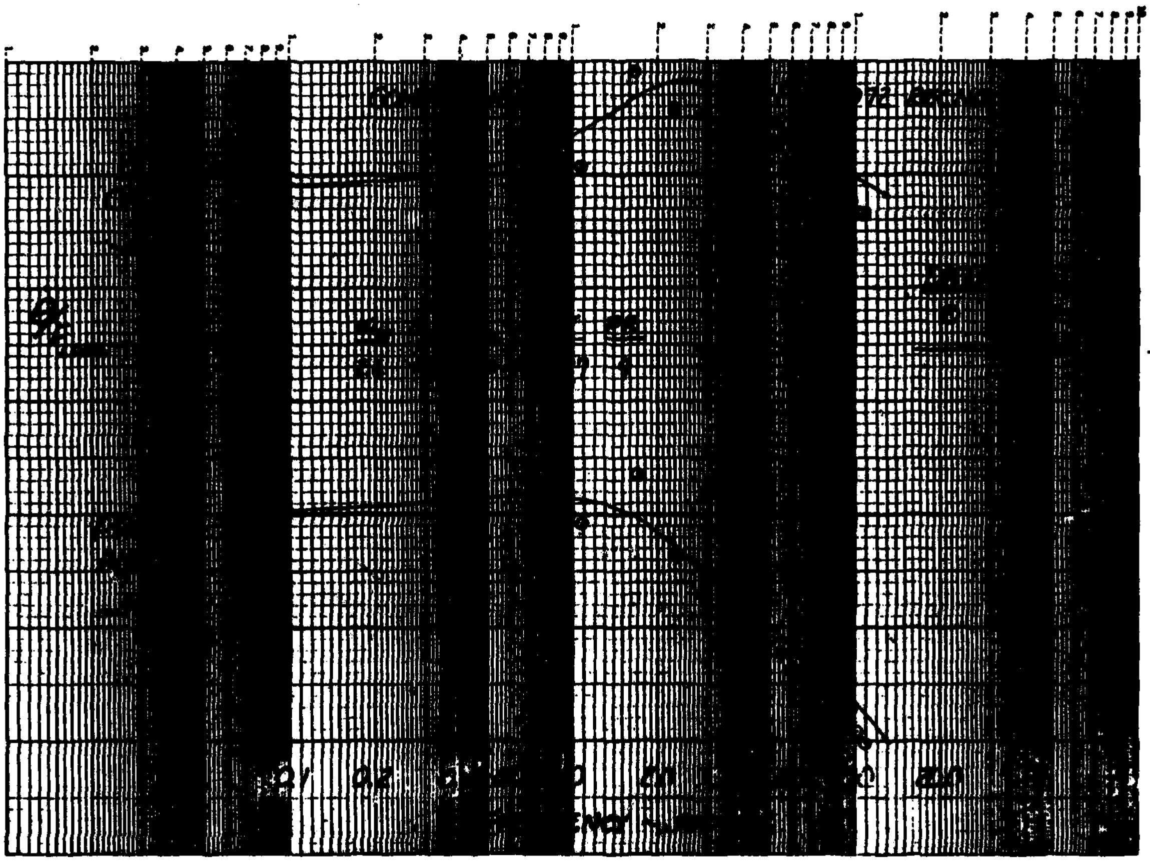


Figure E-24a. Flight Characteristics - Time History



GP13-0824-08

Figure E-24b. Flight Characteristics - Pitch Rate Response

CONFIG P 120 - LANDING NO. 2 FLT 2086 REC NO. 3

P12A with Gain Changed

Pilot A; PR 8

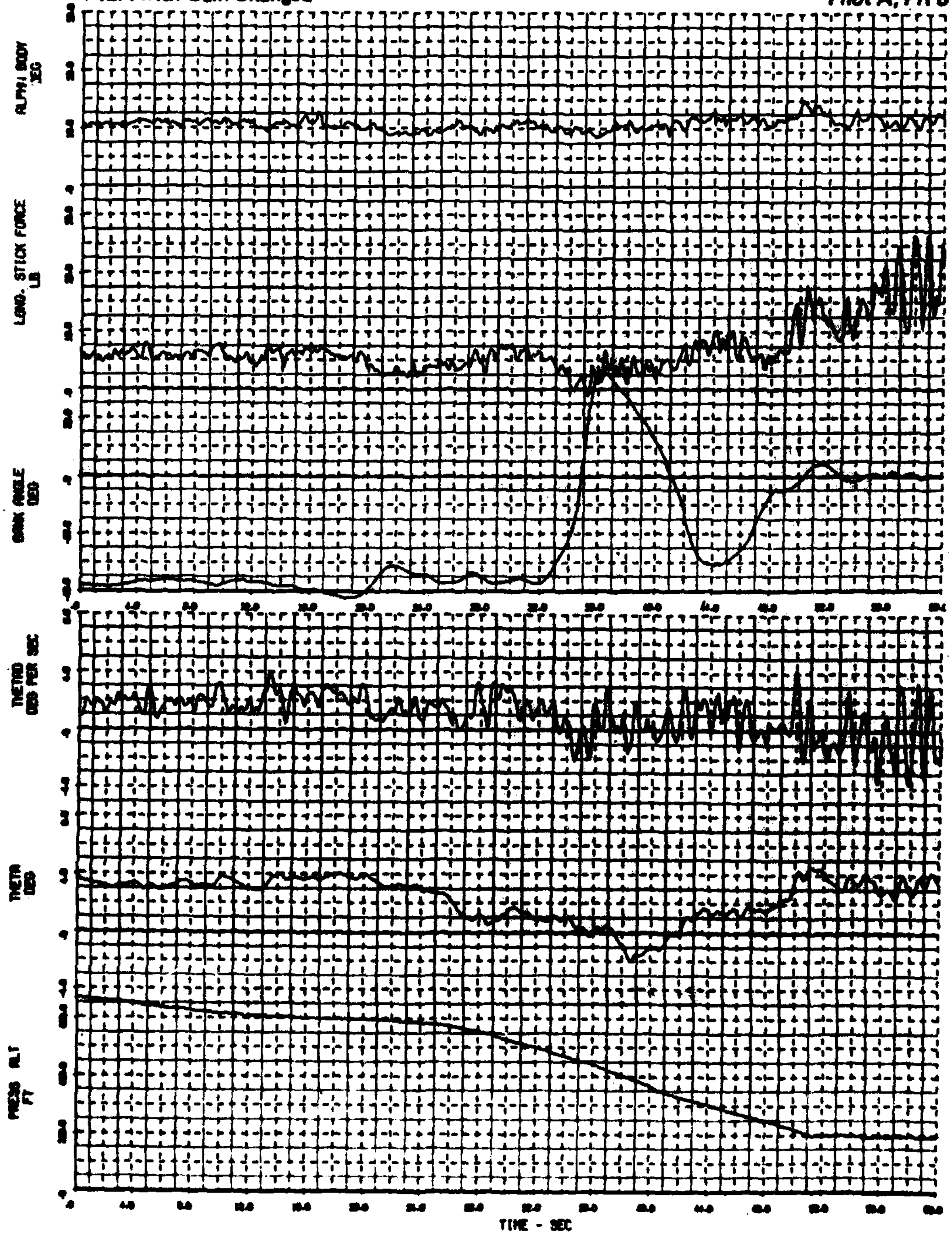
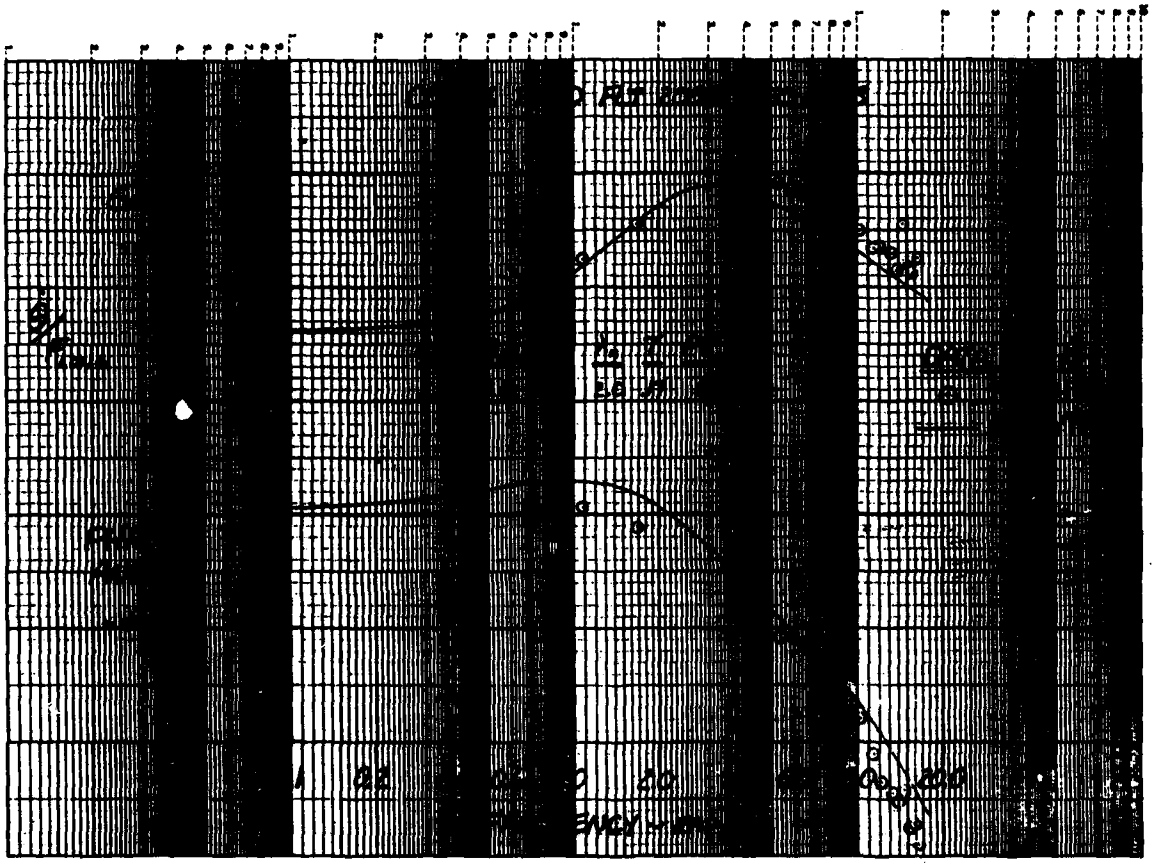


Figure E-29a. Flight Characteristics - Time History



GP13-0684-58

Figure E-25b. Flight Characteristics - Pitch Rate Response

CONFIG P13 - LANDING NO. 2 FLT 2064 REC NO. 4

HOS (LAHOS Configuration 4-7) Force Commands

Pilot A; PR 3

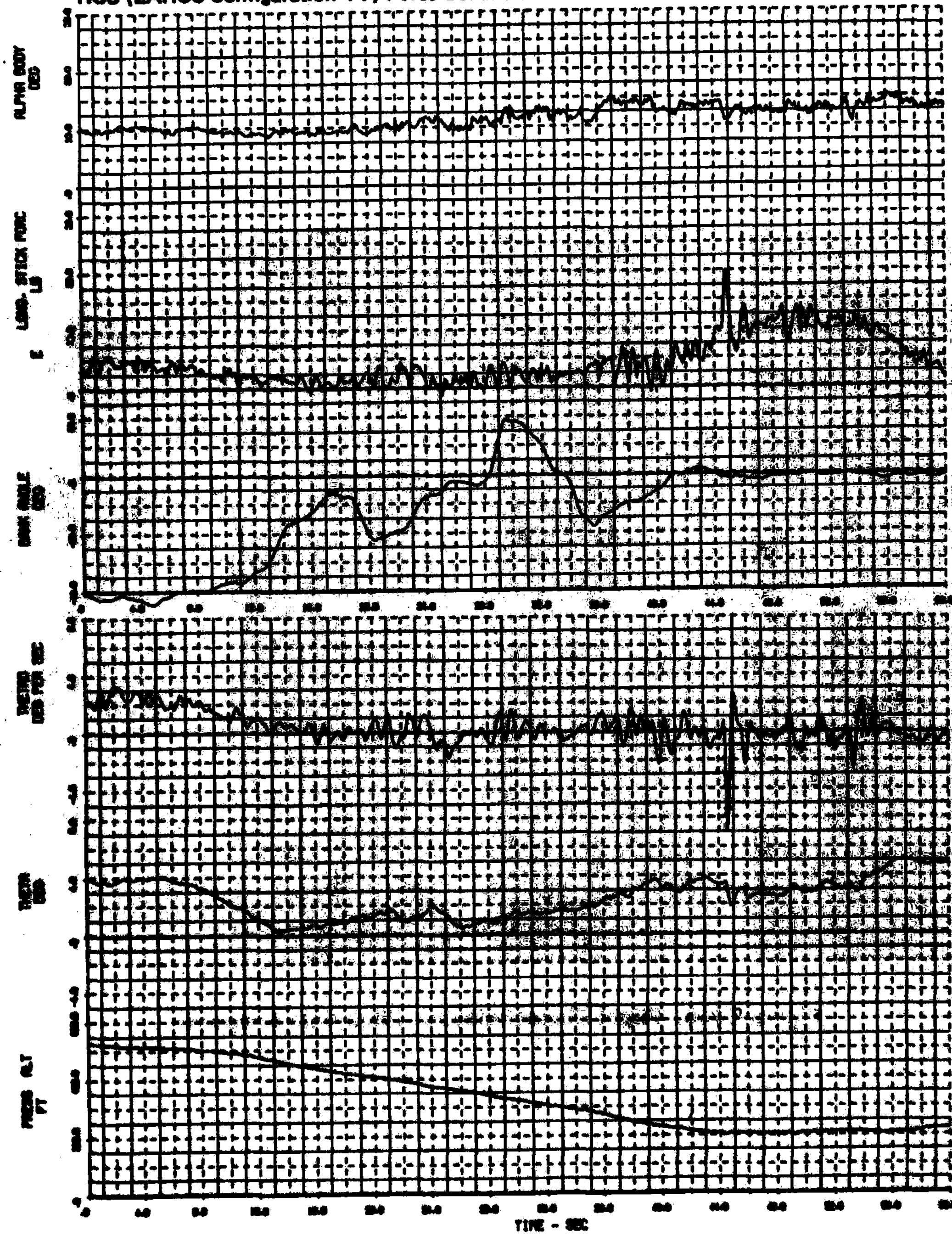
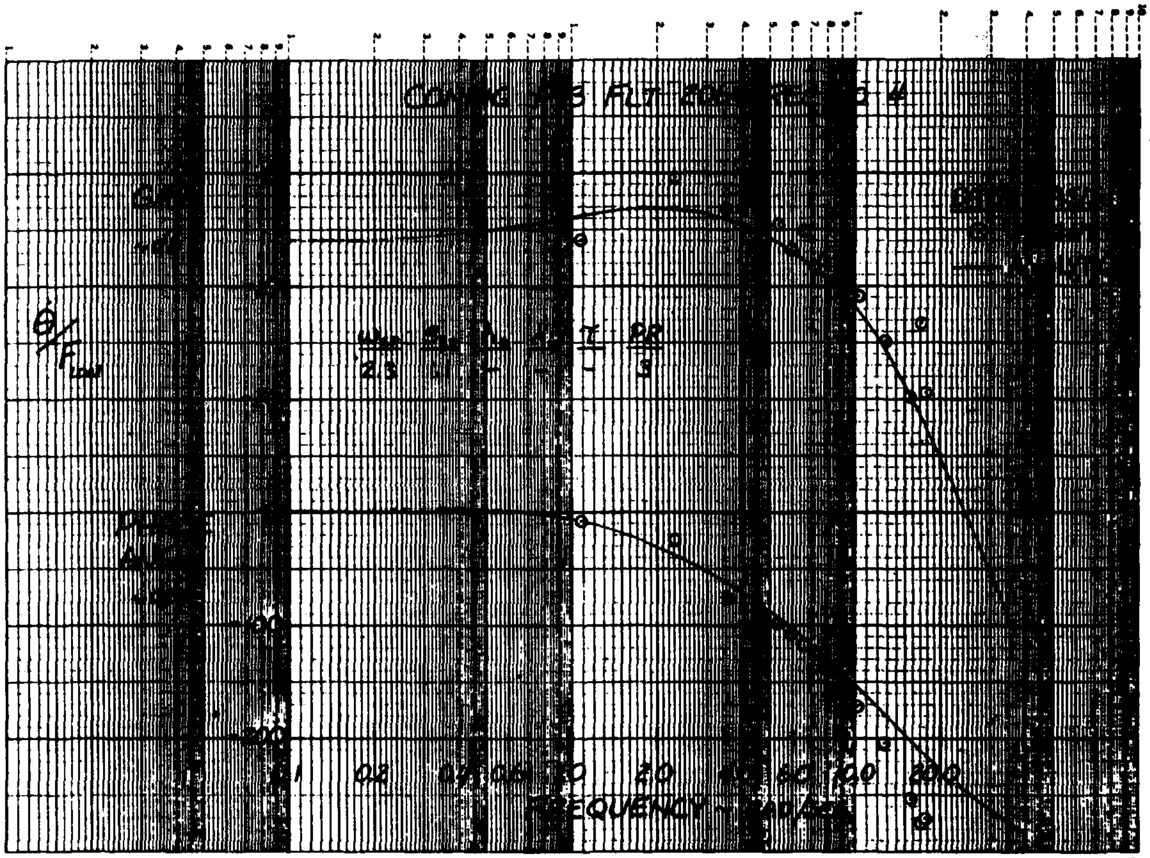


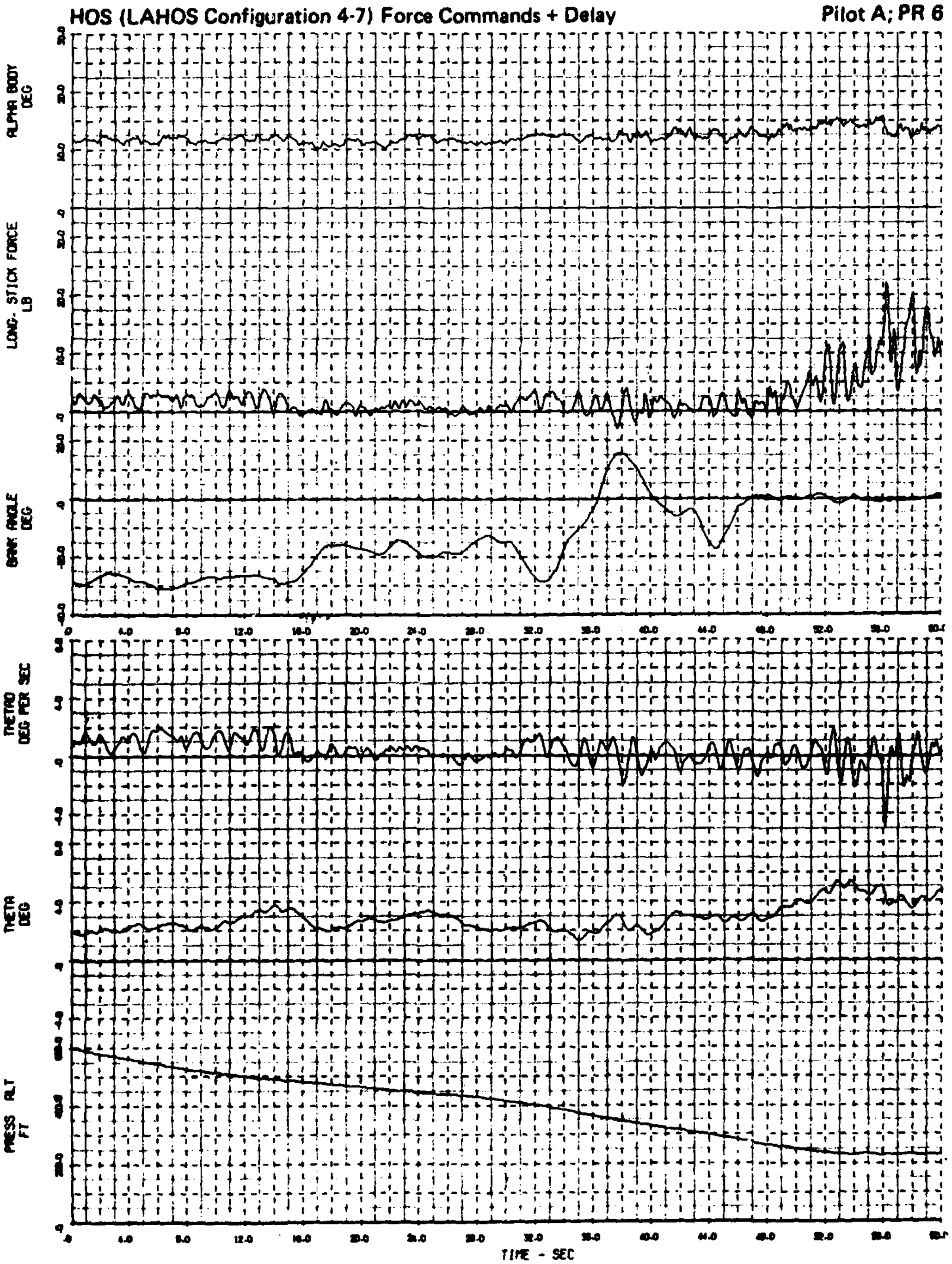
Figure E-26a. Flight Characteristics - Time History



GP13-0894-88

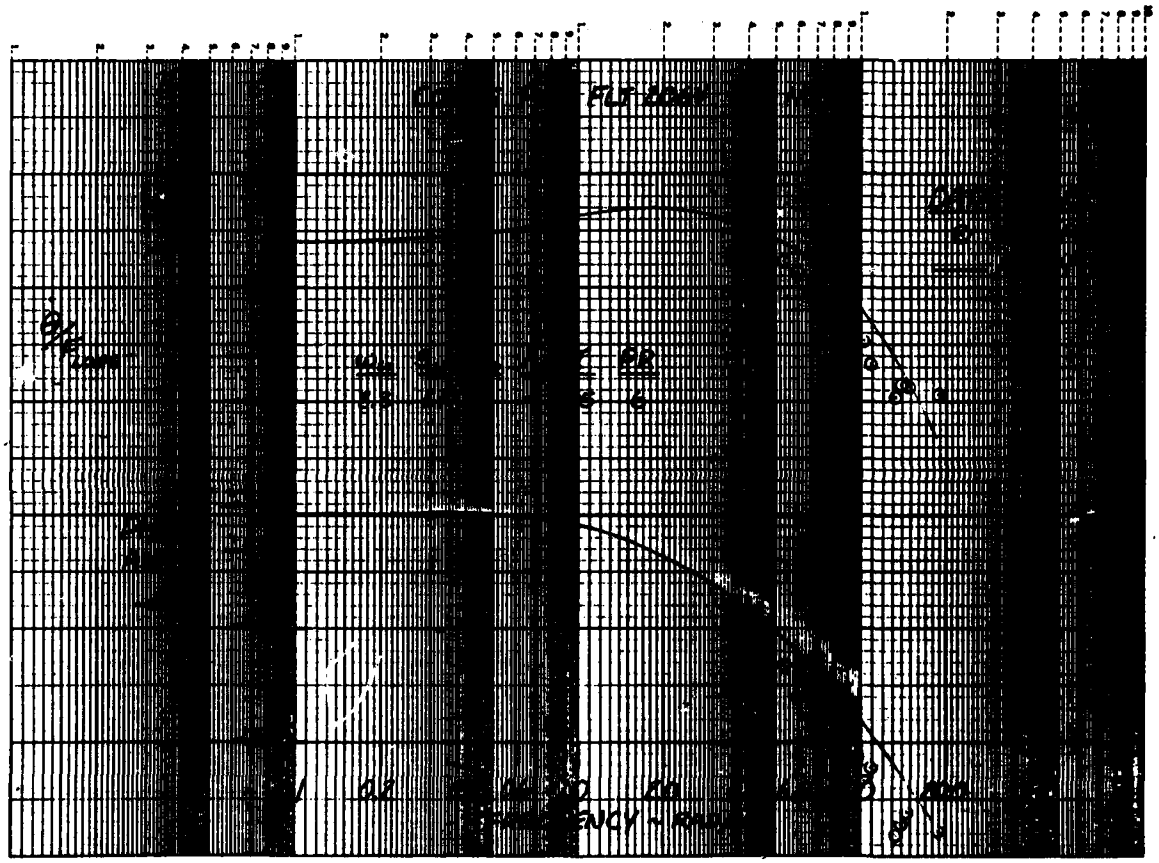
Figure E-28b. Flight Characteristics - Pitch Rate Response

CONFIG P13A- LANDING NO. 2 FLT 2064 REC NO 19



GP13-0684-01

Figure E-27a. Flight Characteristics - Time History



GP13-0624-62

Figure E-27b. Flight Characteristics - Pitch Rate Response

CONFIG P 14- LANDING NO. 2   FLT 2064 REC NO. 12

ES for P13 Plus Feel System Delay

Pilot A; PR 5

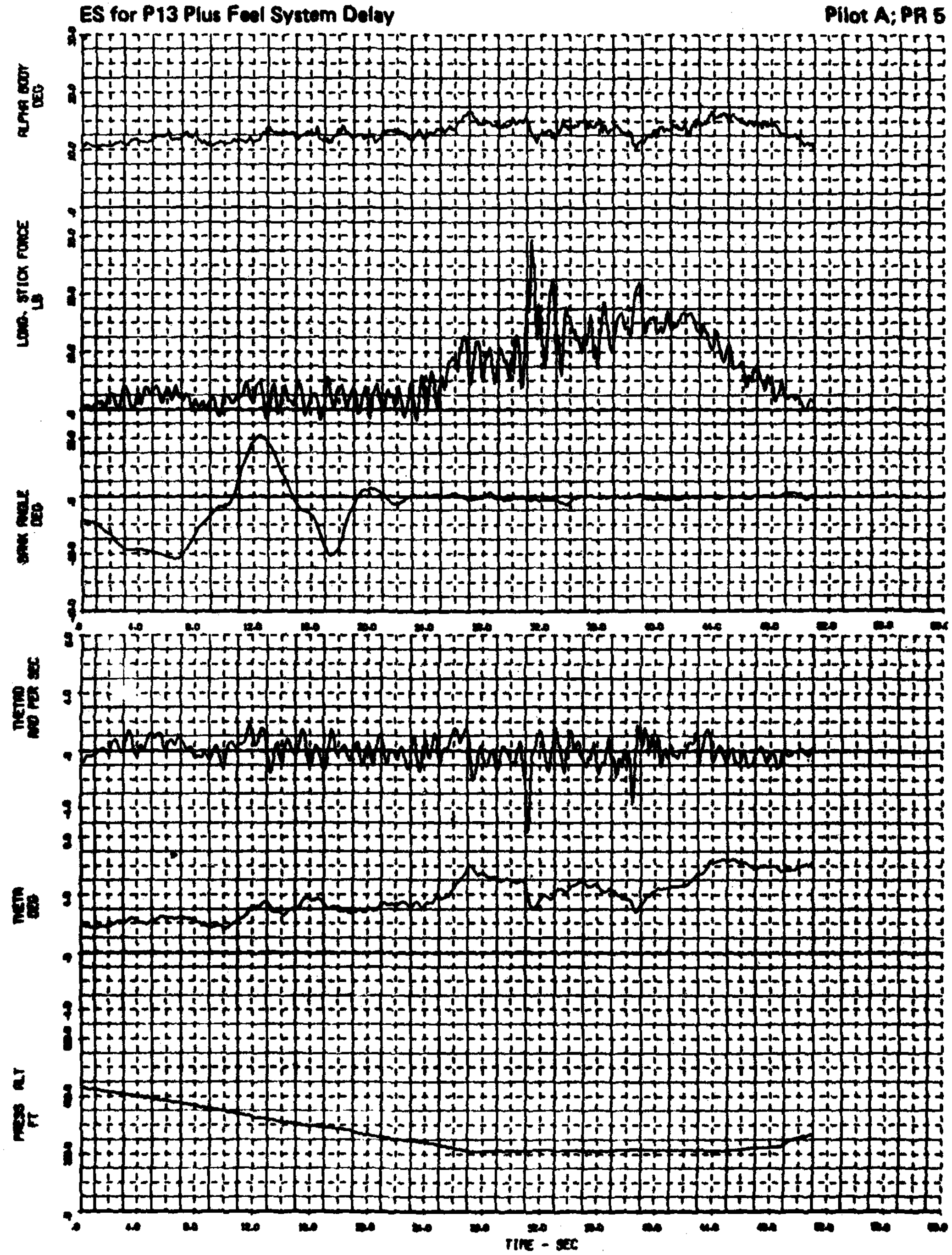


Figure E-28a. Flight Characteristics - Time History

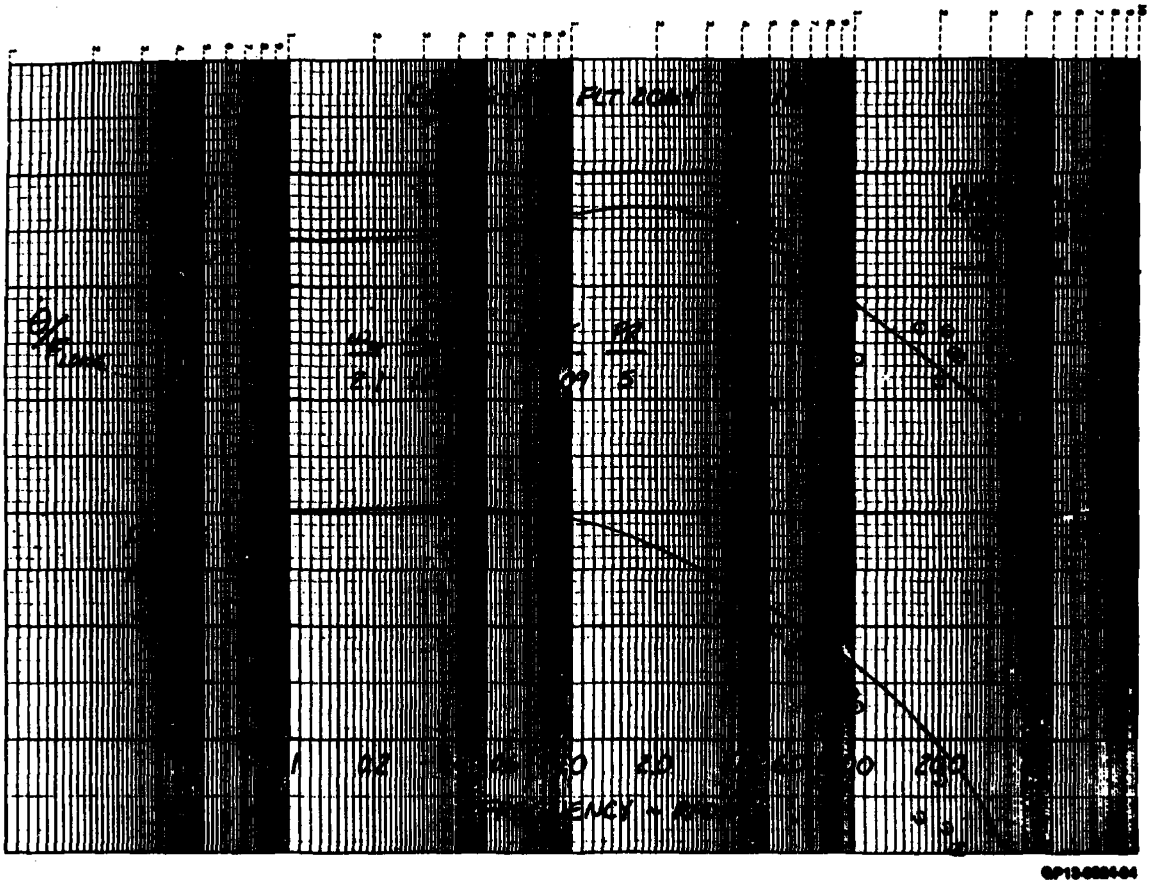
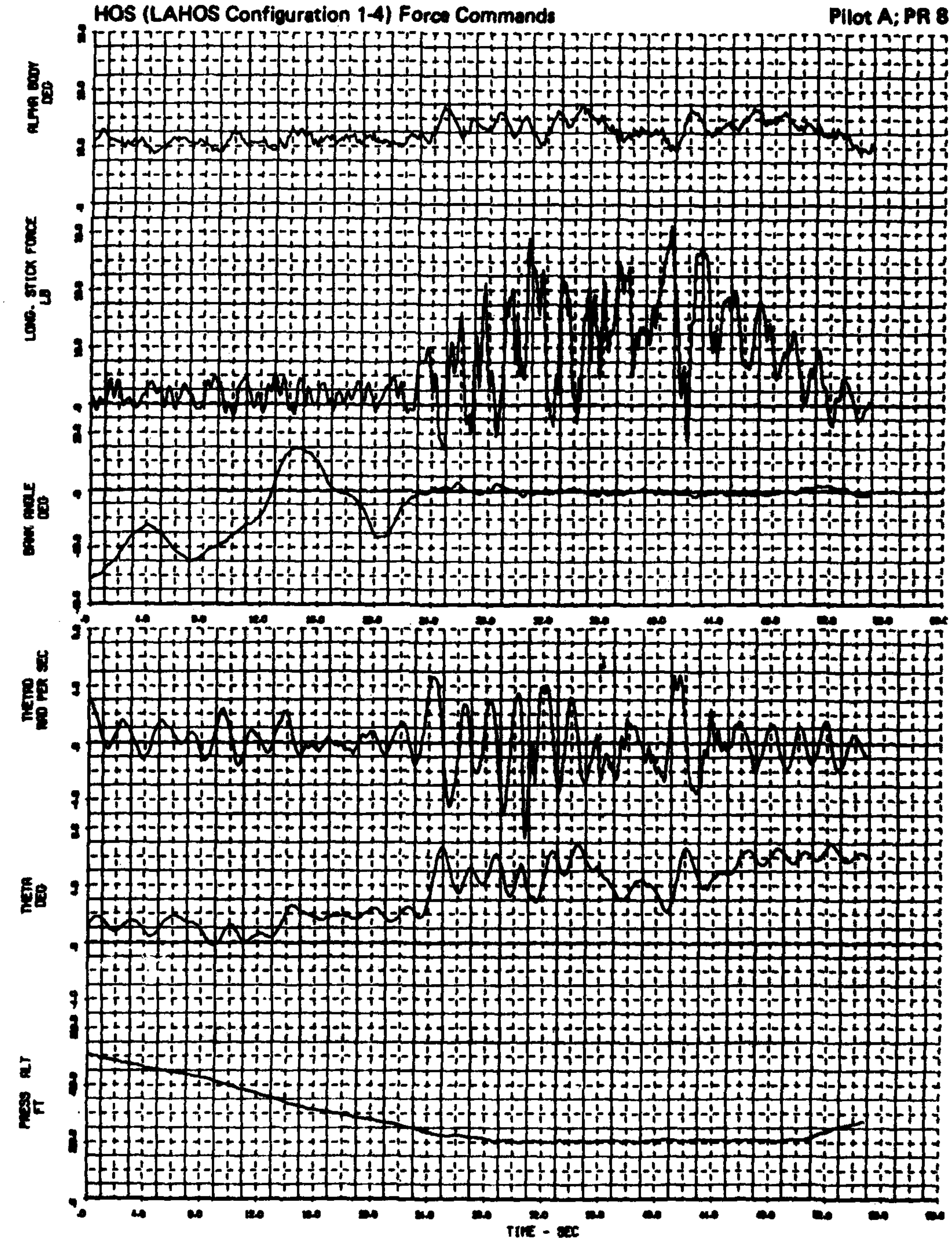


Figure E-28b. Flight Characteristics - Pitch Rate Response

CONFIG P15 - LANDING NO. 2 FLT 2064 REC NO. 7

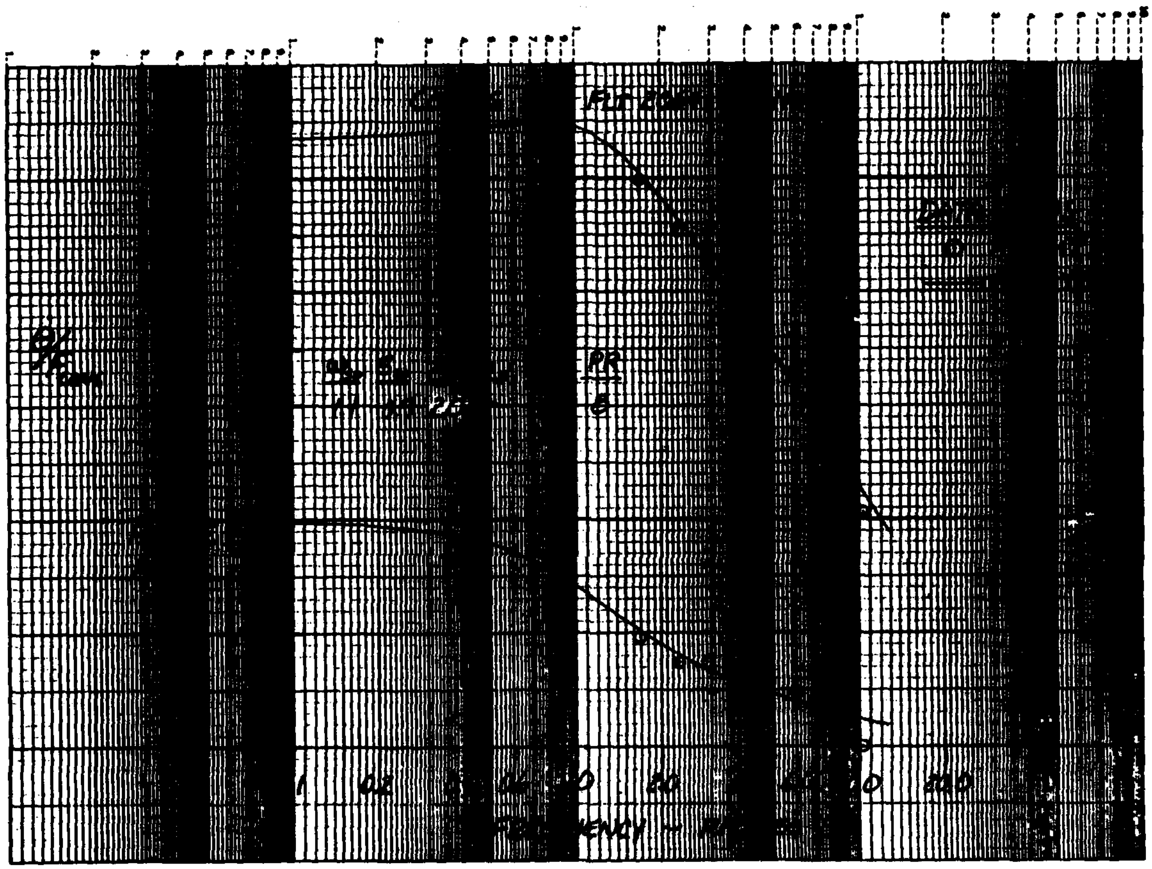
HOS (LAHOS Configuration 1-4) Force Commands

Pilot A; PR 8



GP13-0324-65

Figure E-29a. Flight Characteristics - Time History



GP13-0624-68

Figure E-29b. Flight Characteristics - Pitch Rate Response

CONFIG P16 - LANDING NO. 2 FLT 2072 REC NO. 8

ES for P15, L_{α} Fixed

Pilot A; PR 8

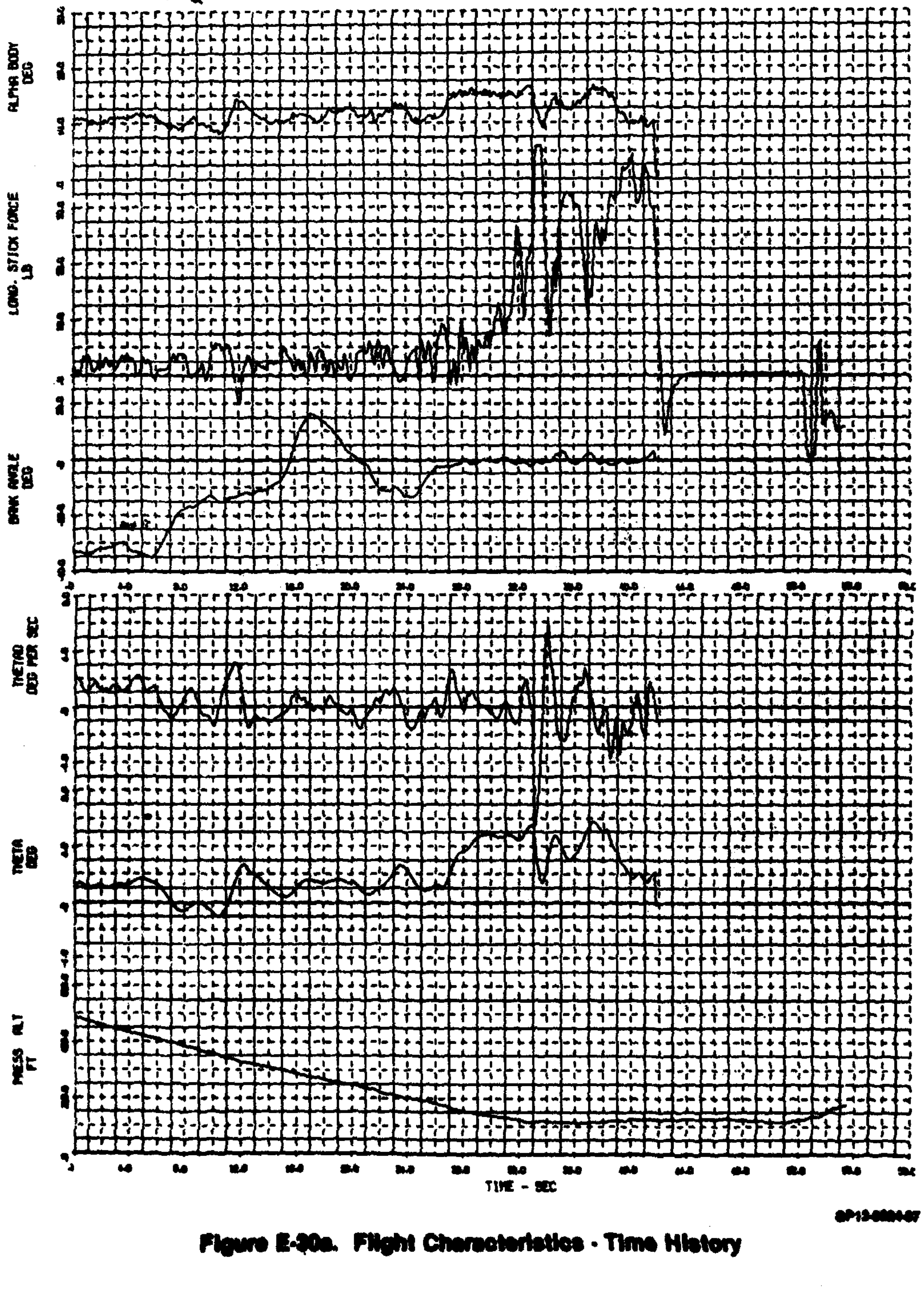
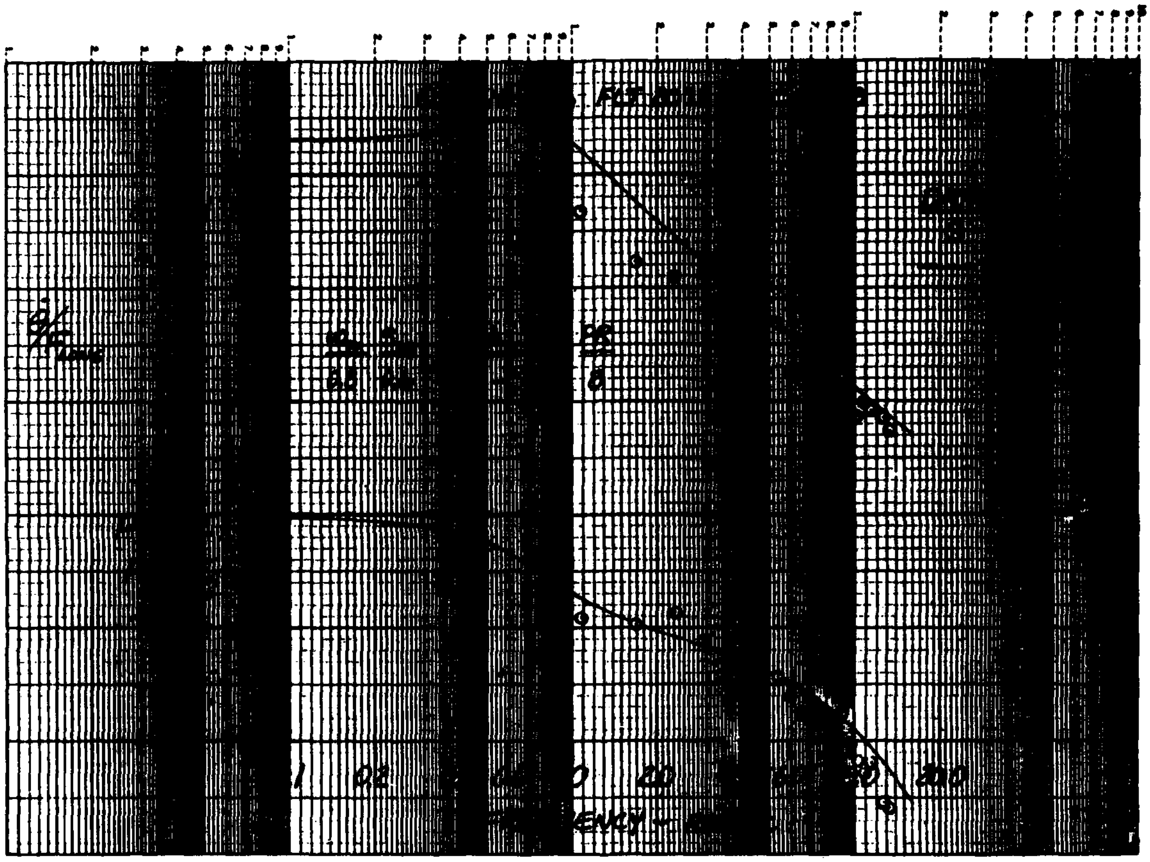


Figure E-30a. Flight Characteristics - Time History



GP13-0224-69

Figure E-30b. Flight Characteristics - Pitch Rate Response

CONFIG P16A - LANDING NO. 2 FLT 2070 REC NO. 15

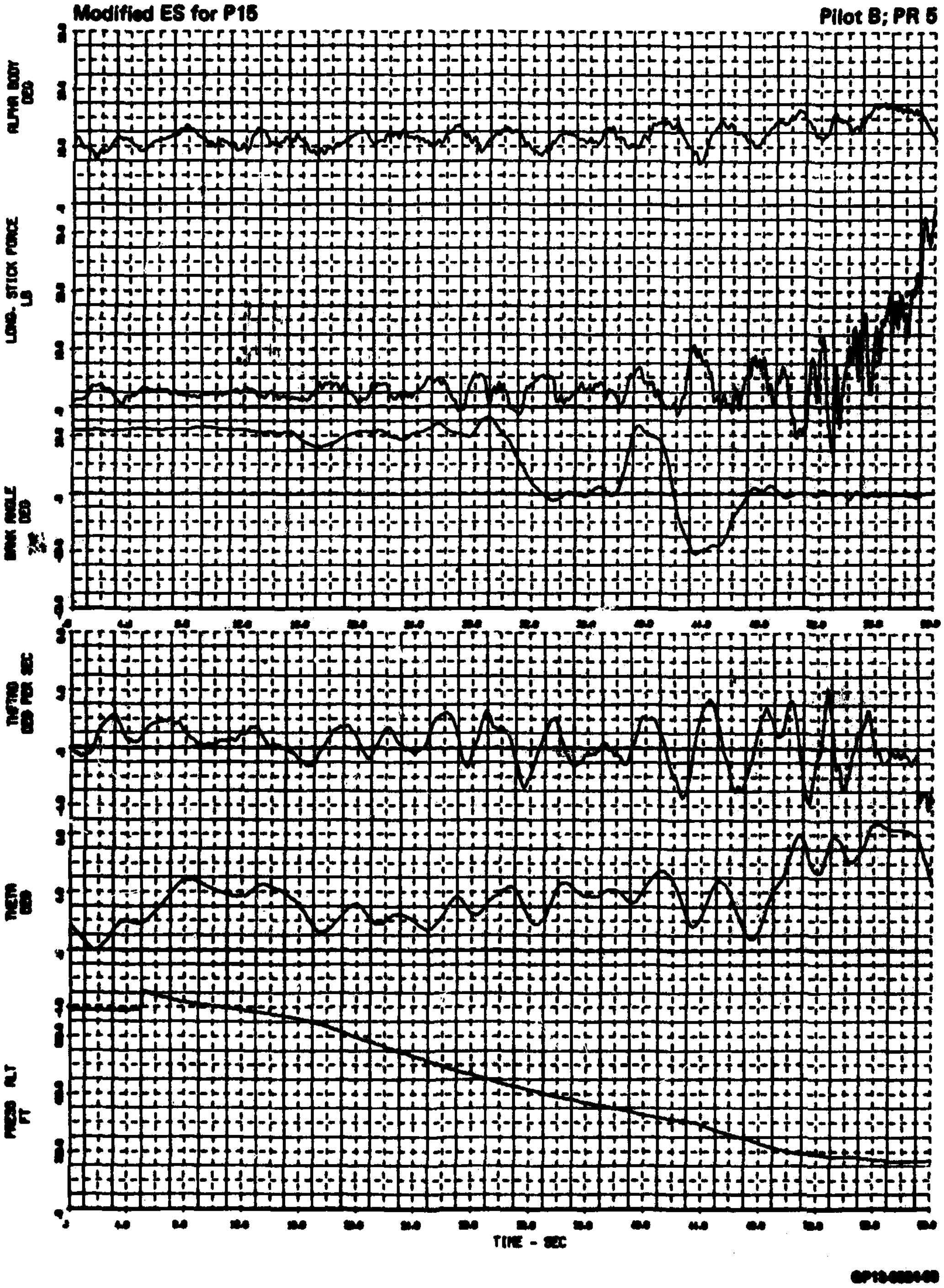


Figure E-31a. Flight Characteristics - Time History

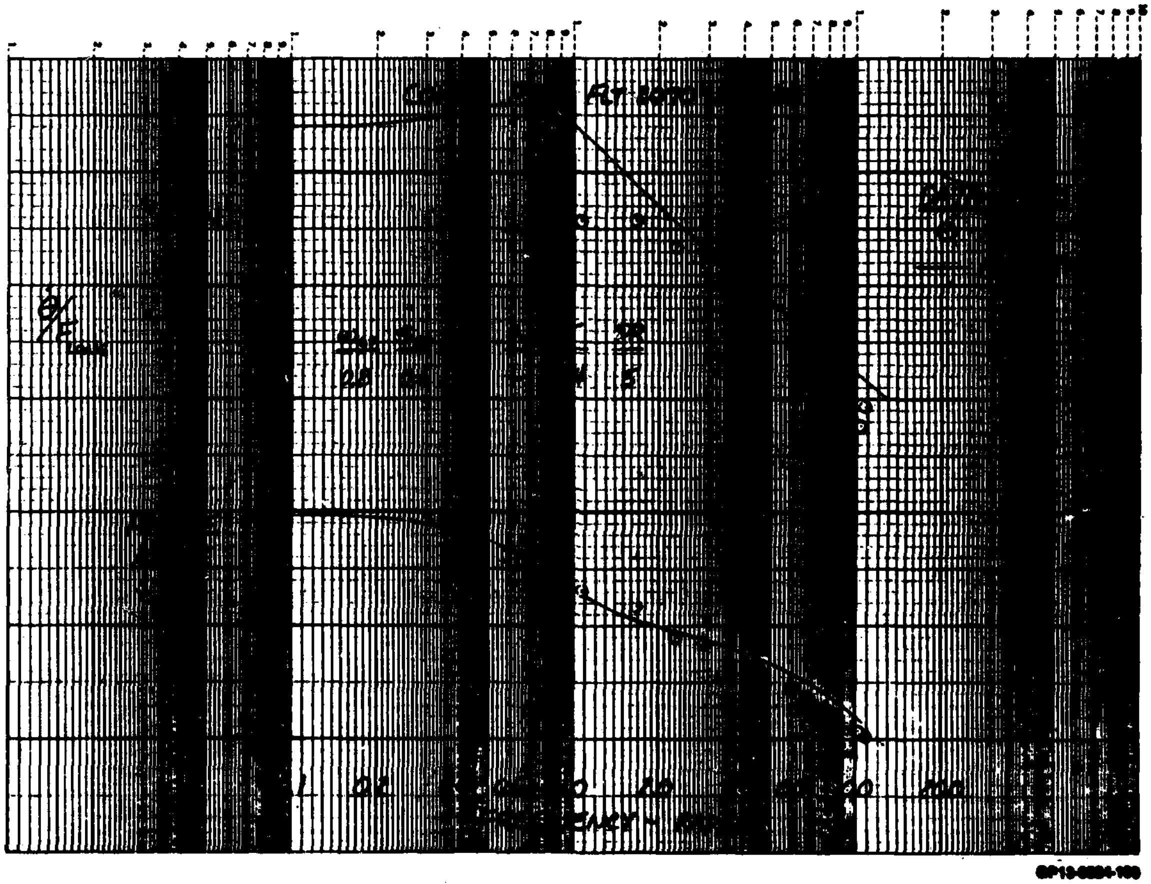
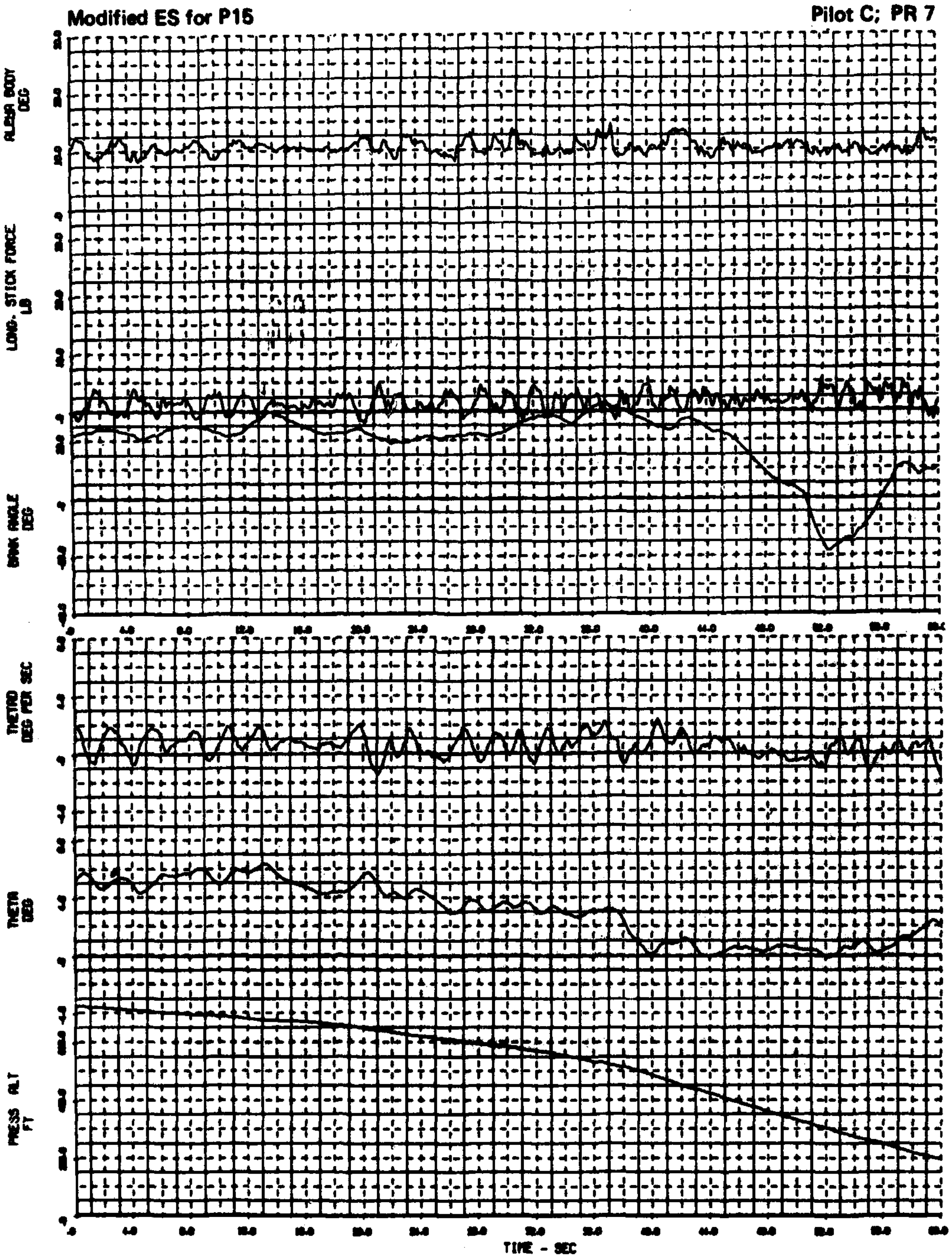


Figure E-31b. Flight Characteristics - Pitch Rate Response

CONFIG P16A - LANDING NO. 2 FLT 2068 REC NO. 10



GP13-0024-181

Figure E-32a. Flight Characteristics - Time History

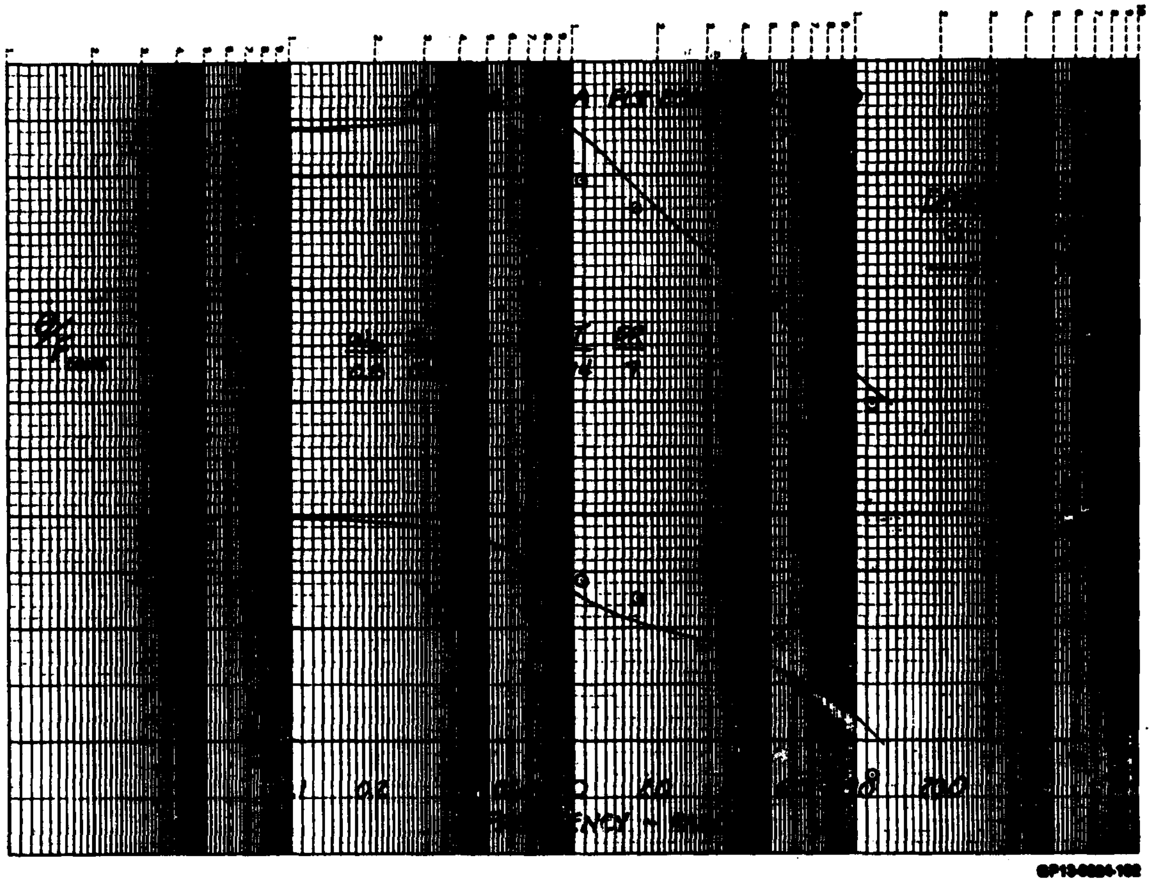


Figure E-32b. Flight Characteristics - Pitch Rate Response

CONFIG P17 - LANDING NO. 2 FLT 2064 REC NO. 14

ES for P15, L_α Free

Pilot A; PR 9

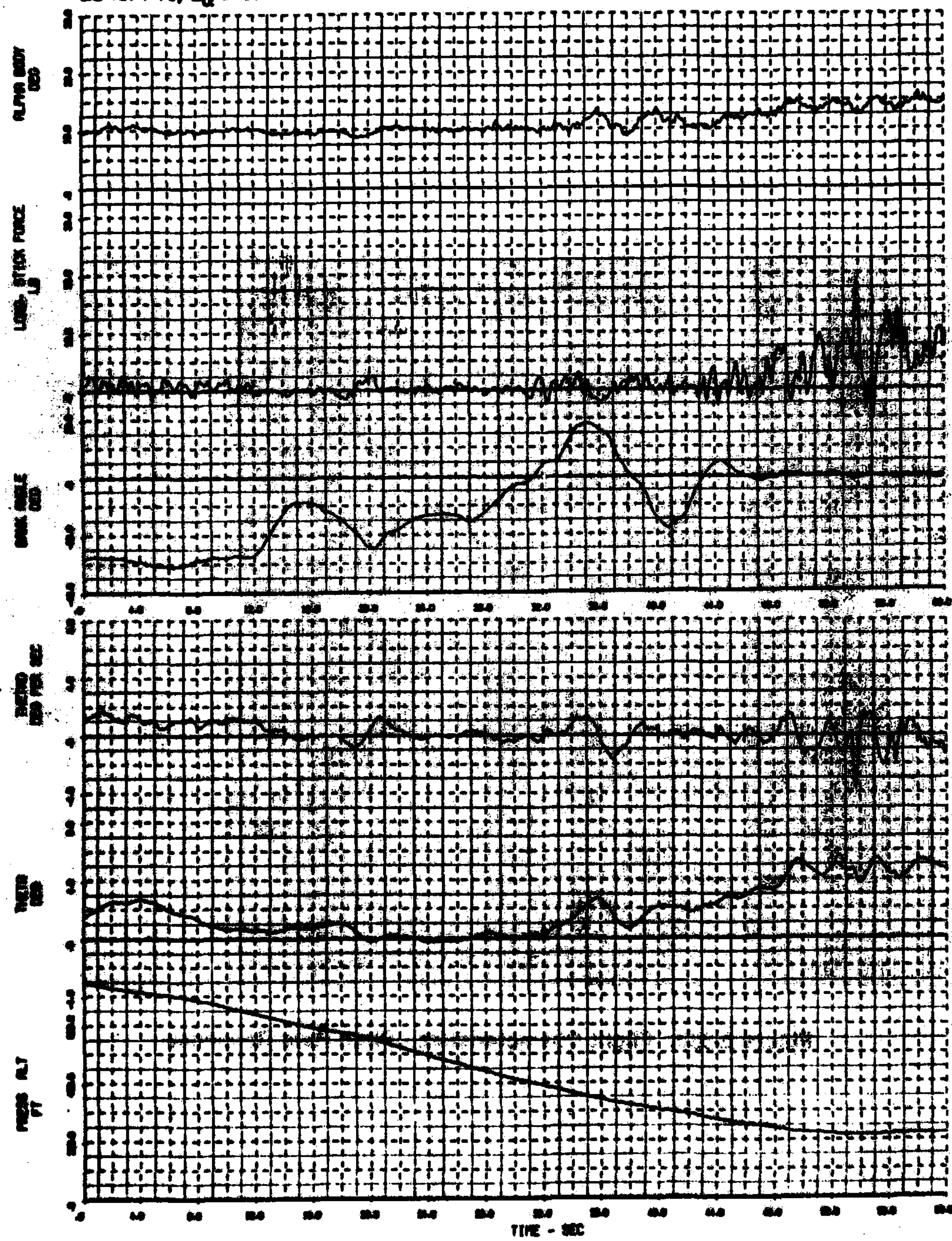
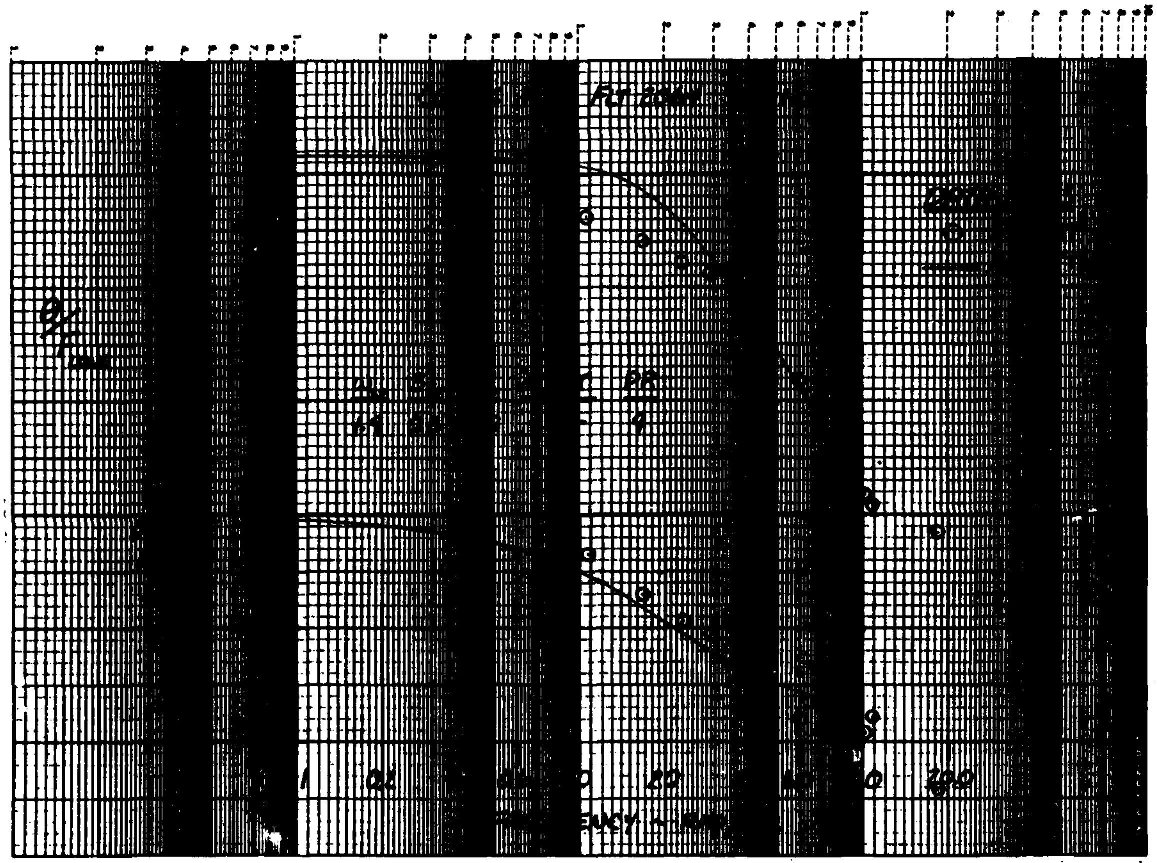


Figure E-83a. Flight Characteristics - Time History



GP13-0884-104

Figure E-33b. Flight Characteristics - Pitch Rate Response

CONFIG L3 - LANDING NO. 2 FLT 2080 REC NO. 8

Adv Fighter (HOS-4) Pilot A; PR 4

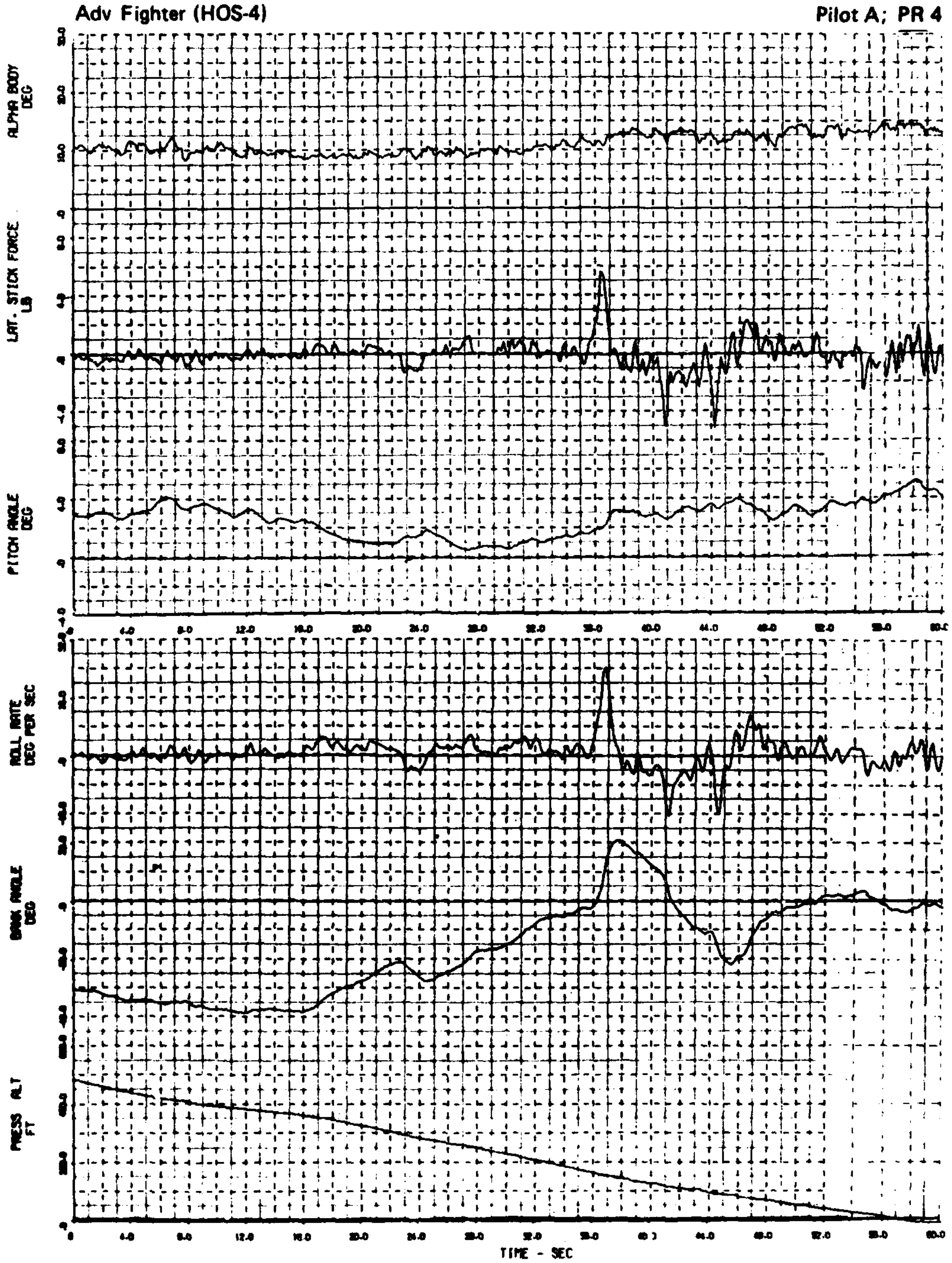
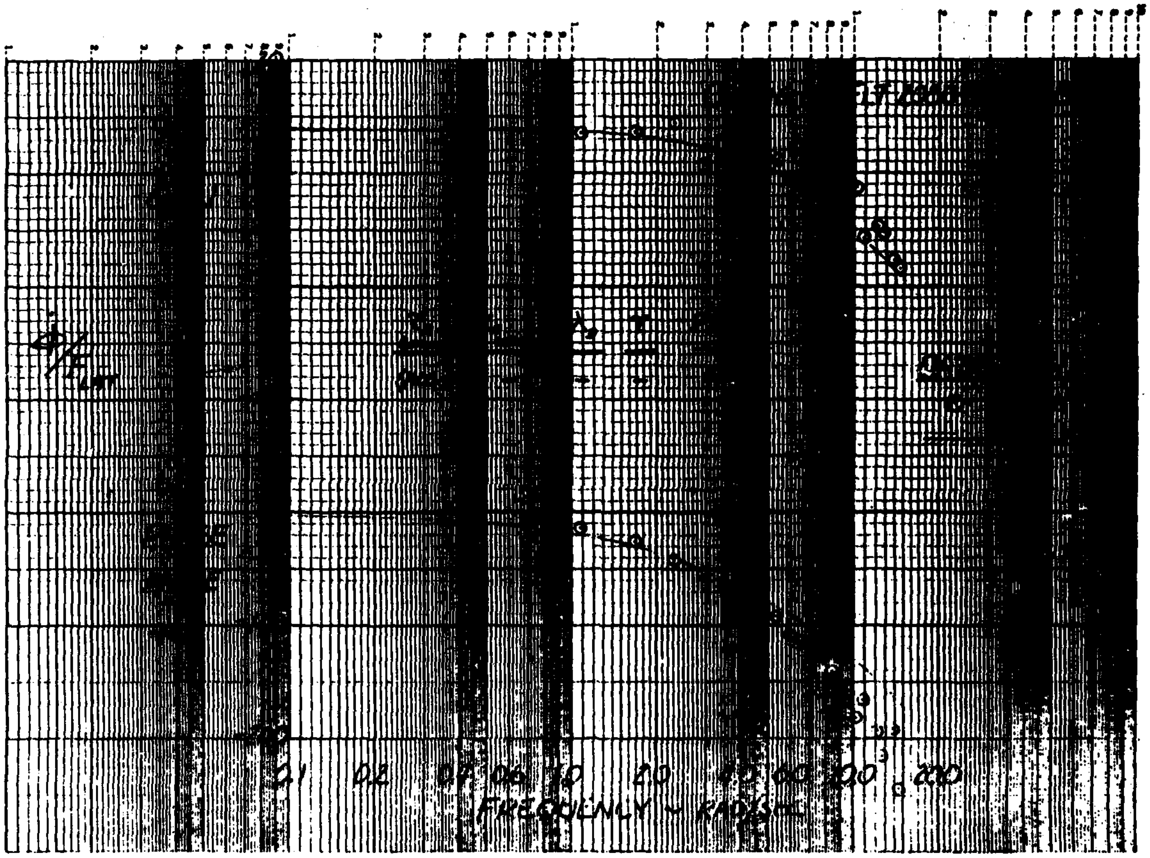


Figure E-34a. Flight Characteristics - Time History



GP13-0804-108

Figure E-34b. Flight Characteristics - Roll Rate Response

CONFIG L4 - LANDING NO. 2 FLT 2080 REC NO. 16

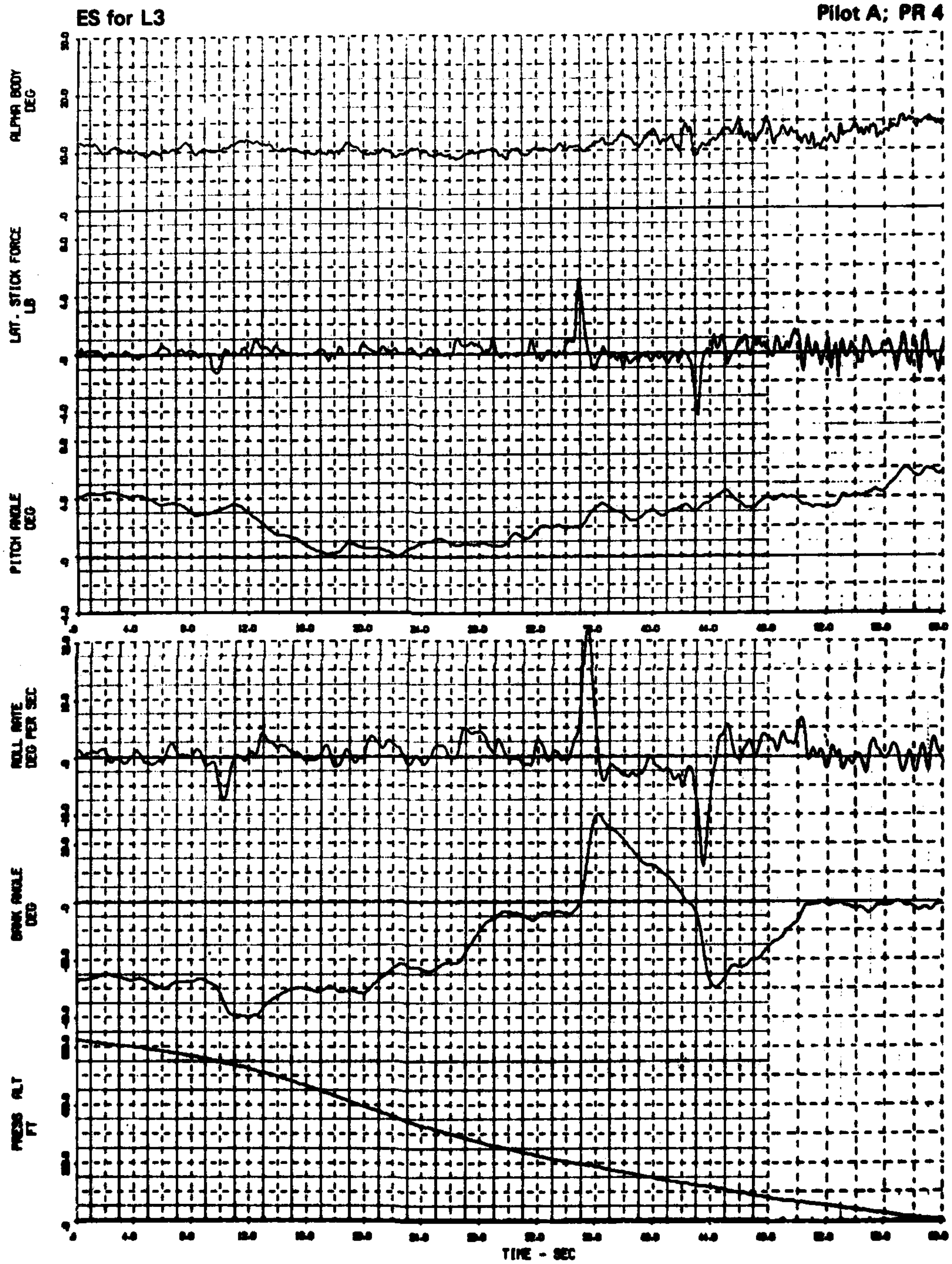
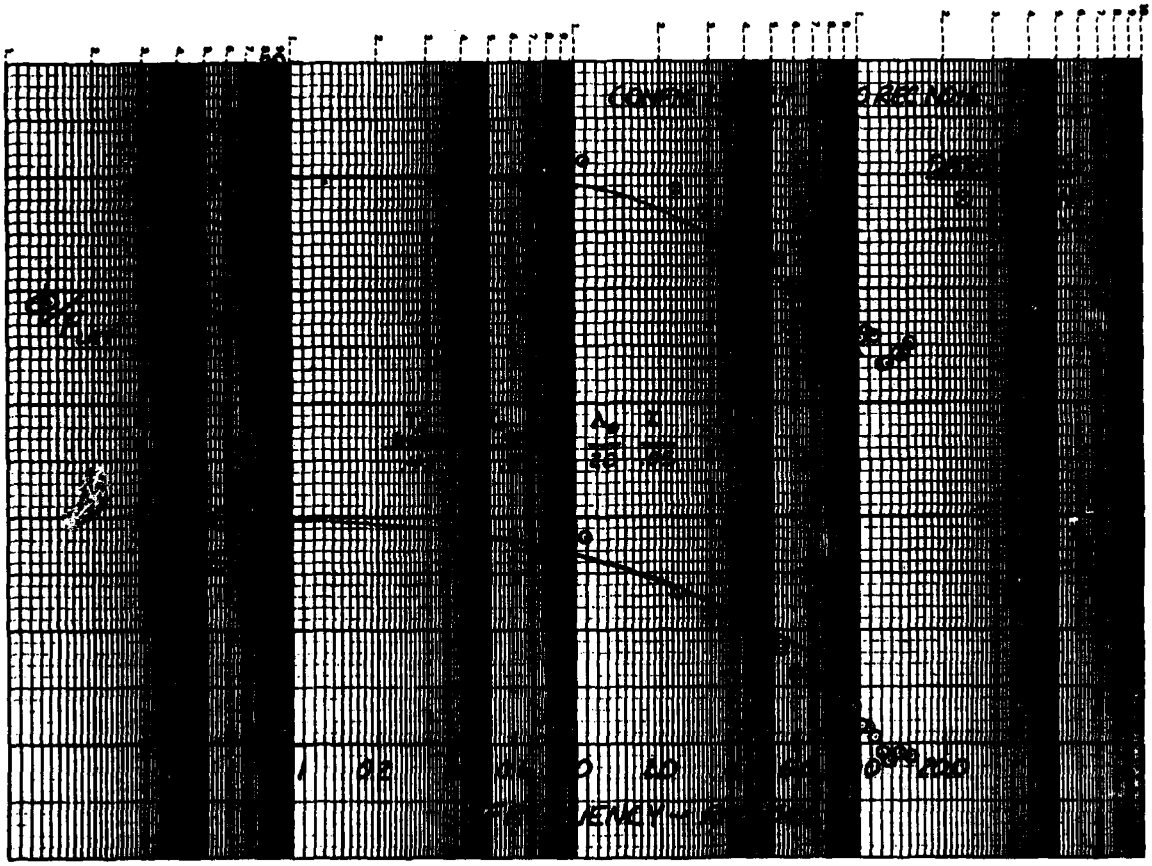


Figure E-35a. Flight Characteristics - Time History

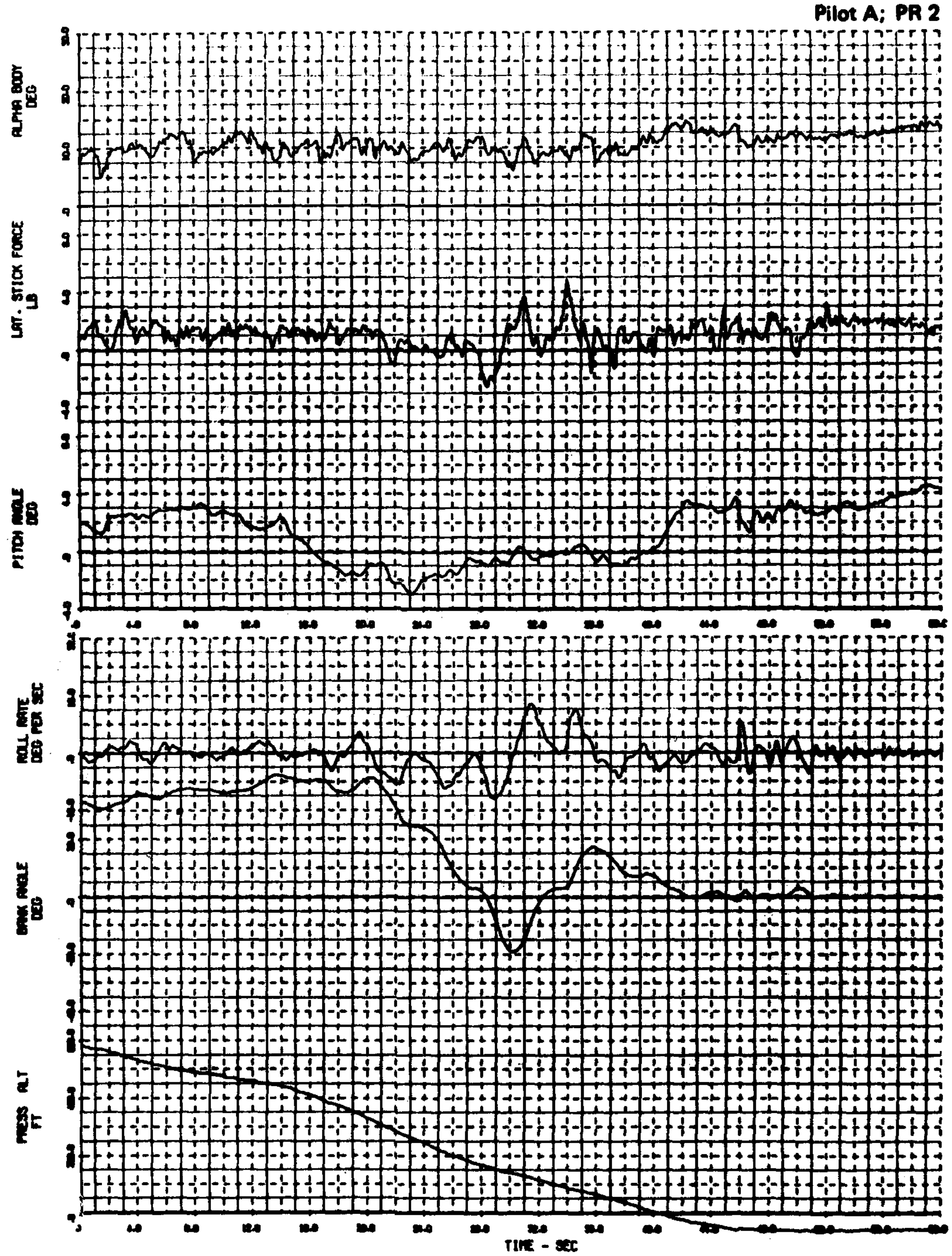


GP13-0394-108

Figure E-35b. Flight Characteristics - Roll Rate Response

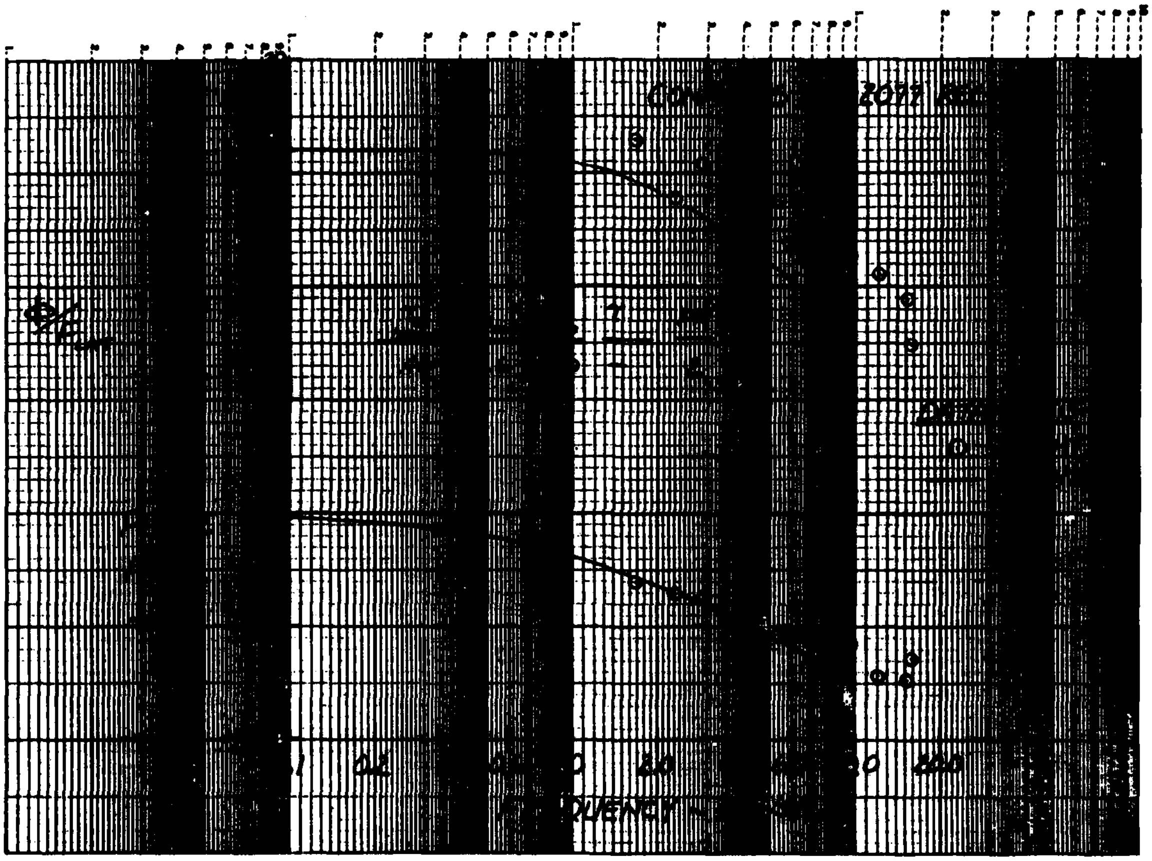
CONFIG L5 - LANDING NO. 2 FLT 2077 REC NO. 4

Pilot A; PR 2



GP10-0026-100

Figure E-36a. Flight Characteristics - Time History

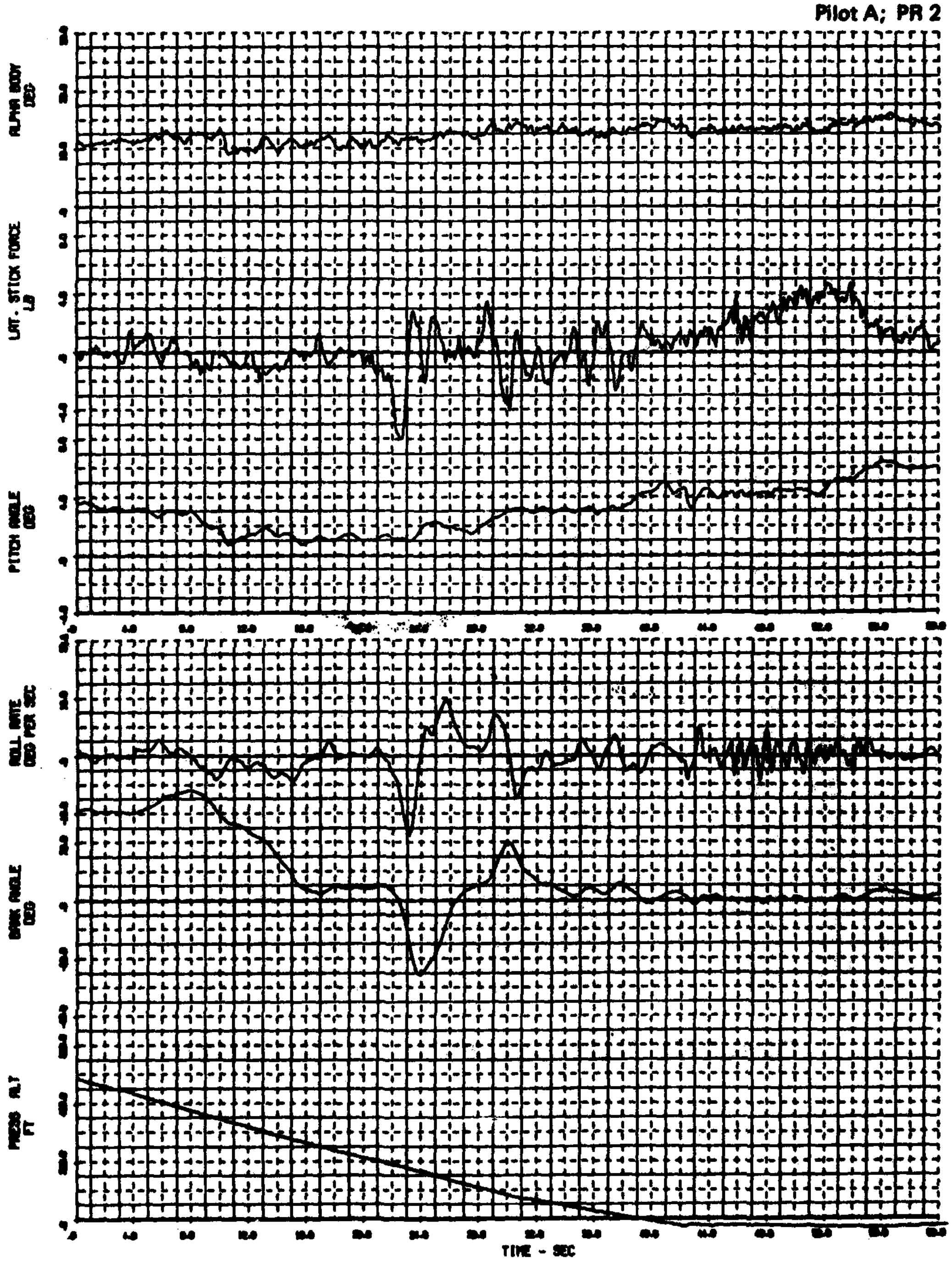


GP13-0024-110

Figure E-36b. Flight Characteristics - Roll Rate Response

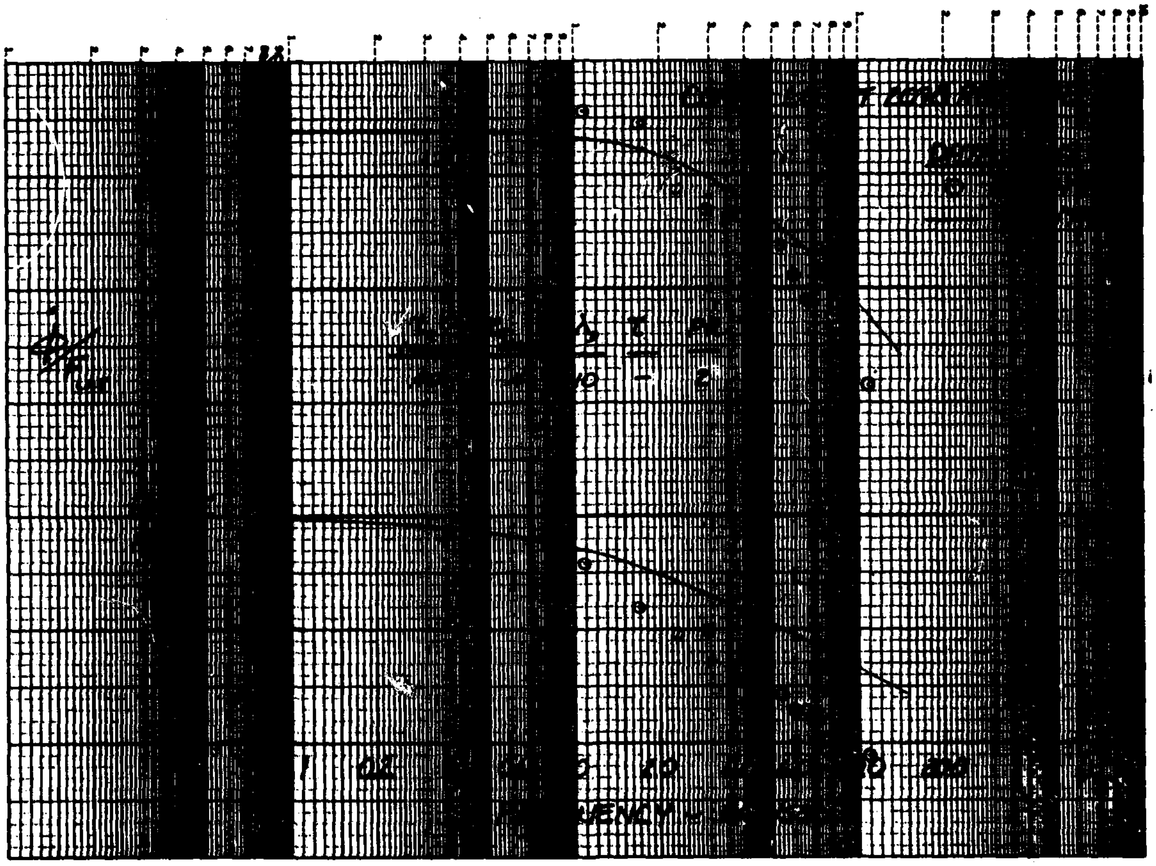
CONFIG L6 -LANDING NO. 2 FLT 2078 REC NO. 16

Pilot A; PR 2



GP13-0224-111

Figure E-37a. Flight Characteristics - Time History

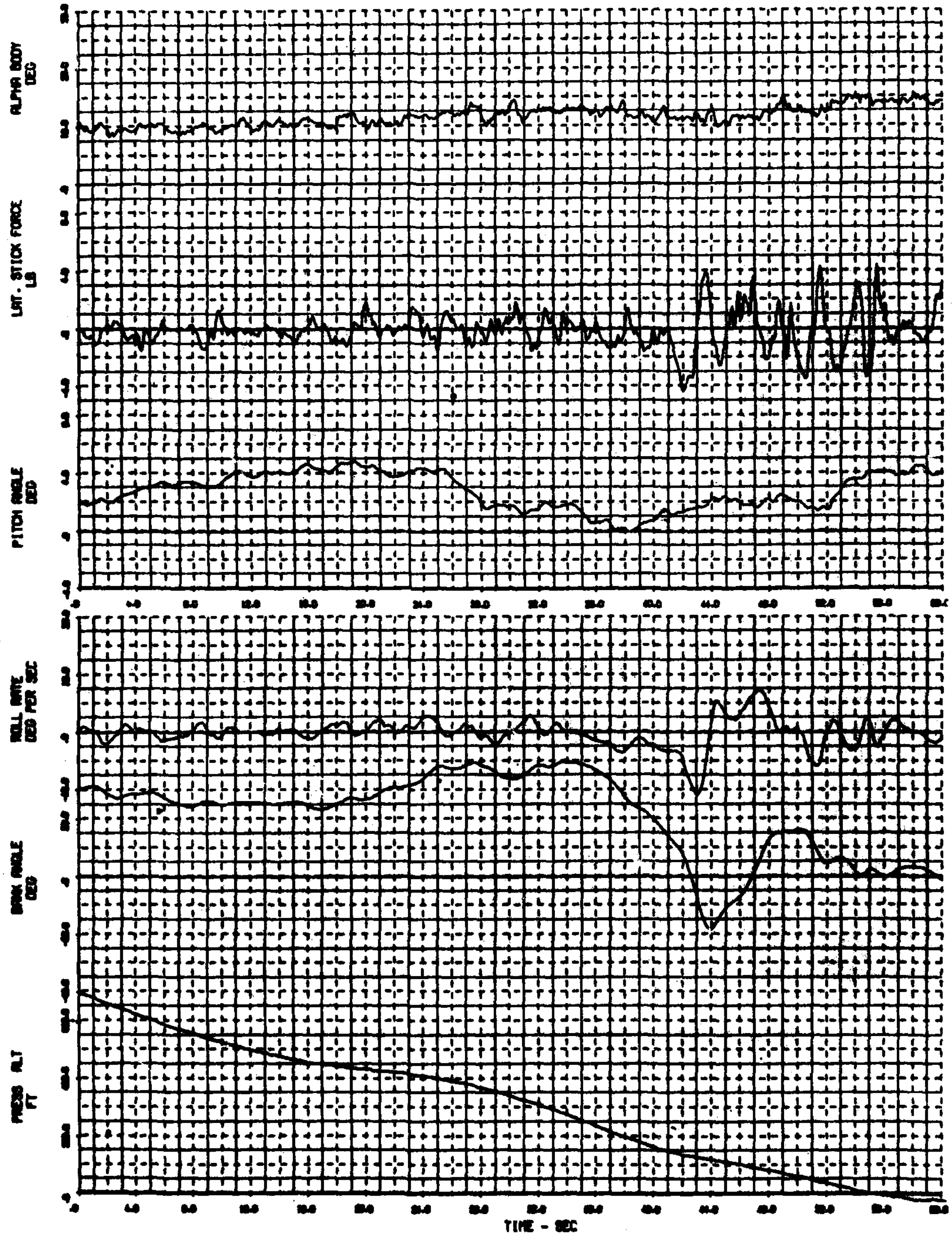


GP10-0084-112

Figure E-37b. Flight Characteristics - Roll Rate Response

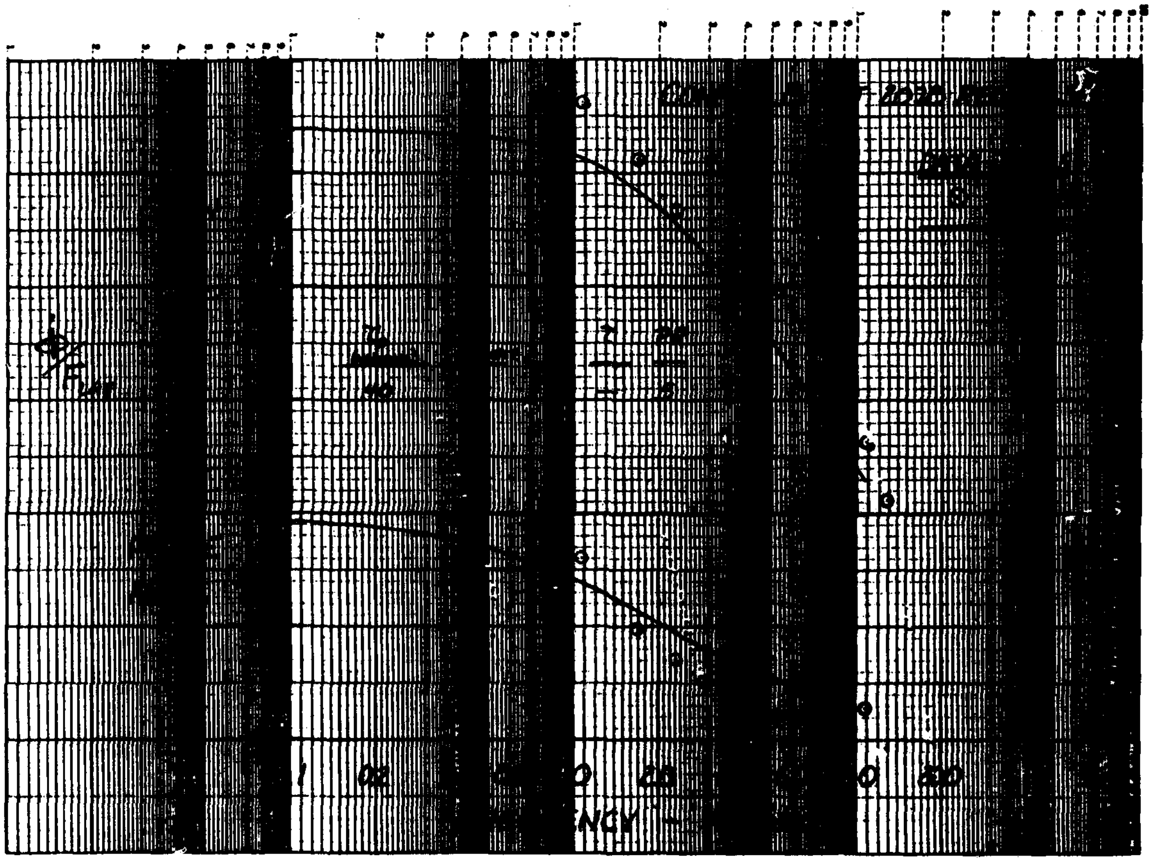
CONFIG L8 - LANDING NO. 2 FLT 2078 REC NO. 3

Pilot A; PR 5



GP13-0224-113

Figure E-38a. Flight Characteristics - Time History

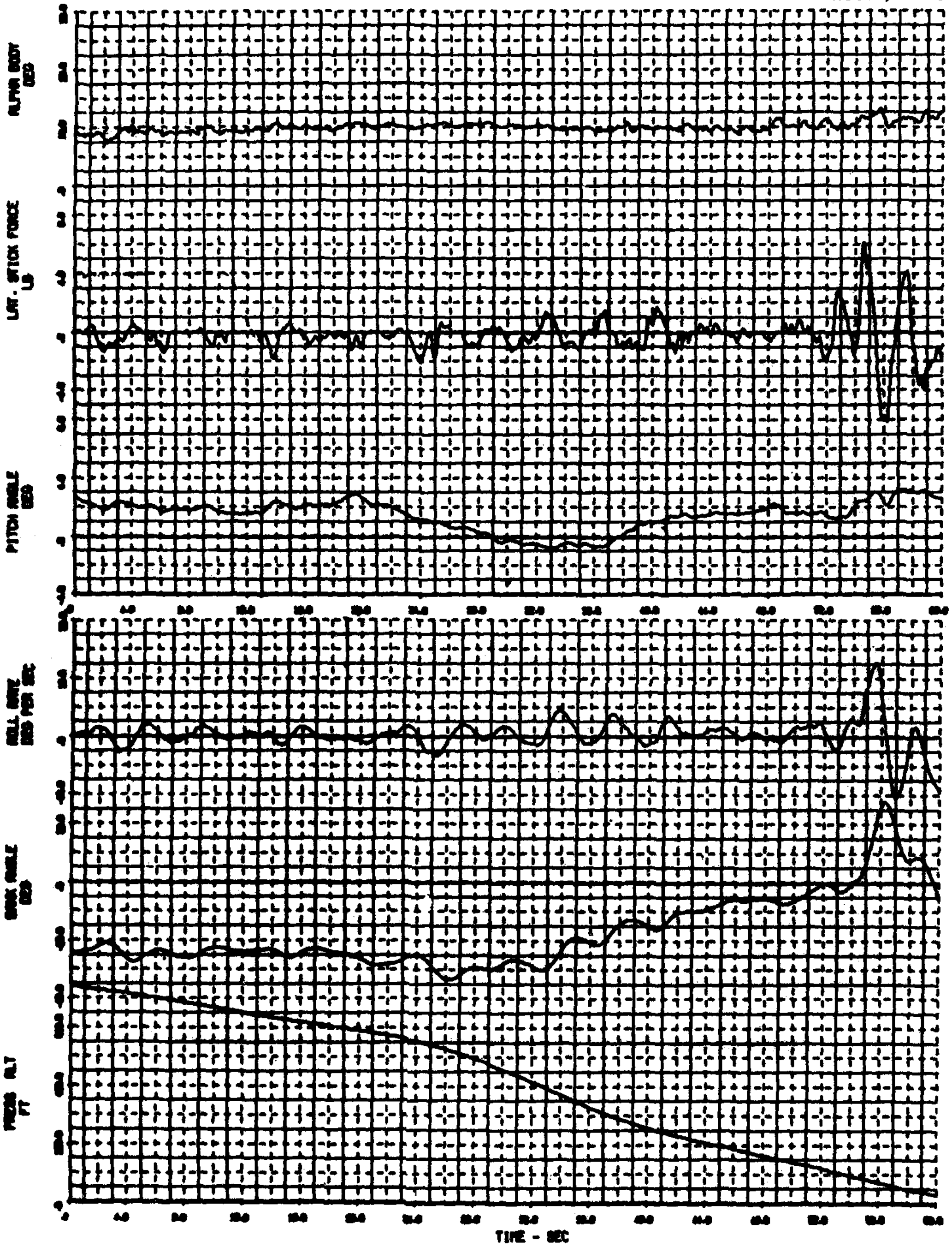


GP13-0284-114

Figure E-38b. Flight Characteristics - Roll Rate Response

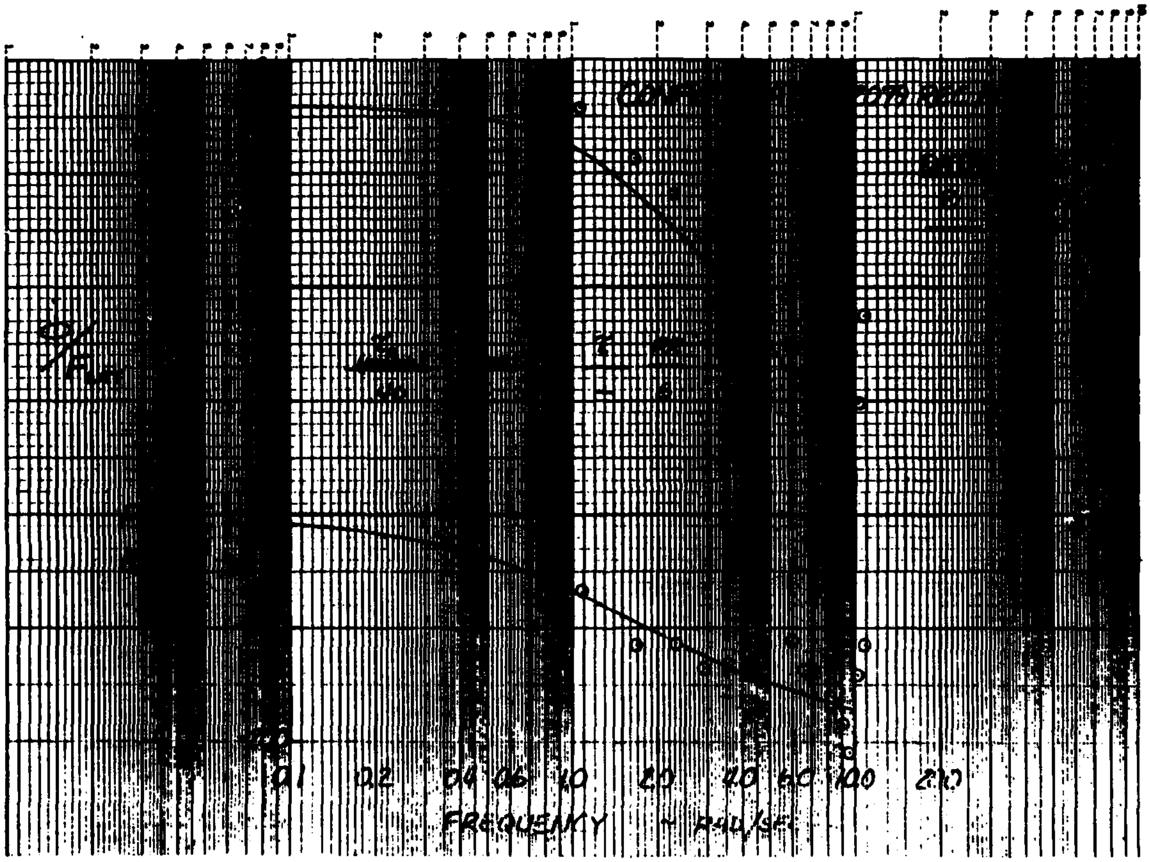
CONFIG L 8A - LANDING NO. 2 FLT 2079 REC NO. 11

Pilot A; PR 6



GP13-0024-116

Figure E-30a. Flight Characteristics - Time History

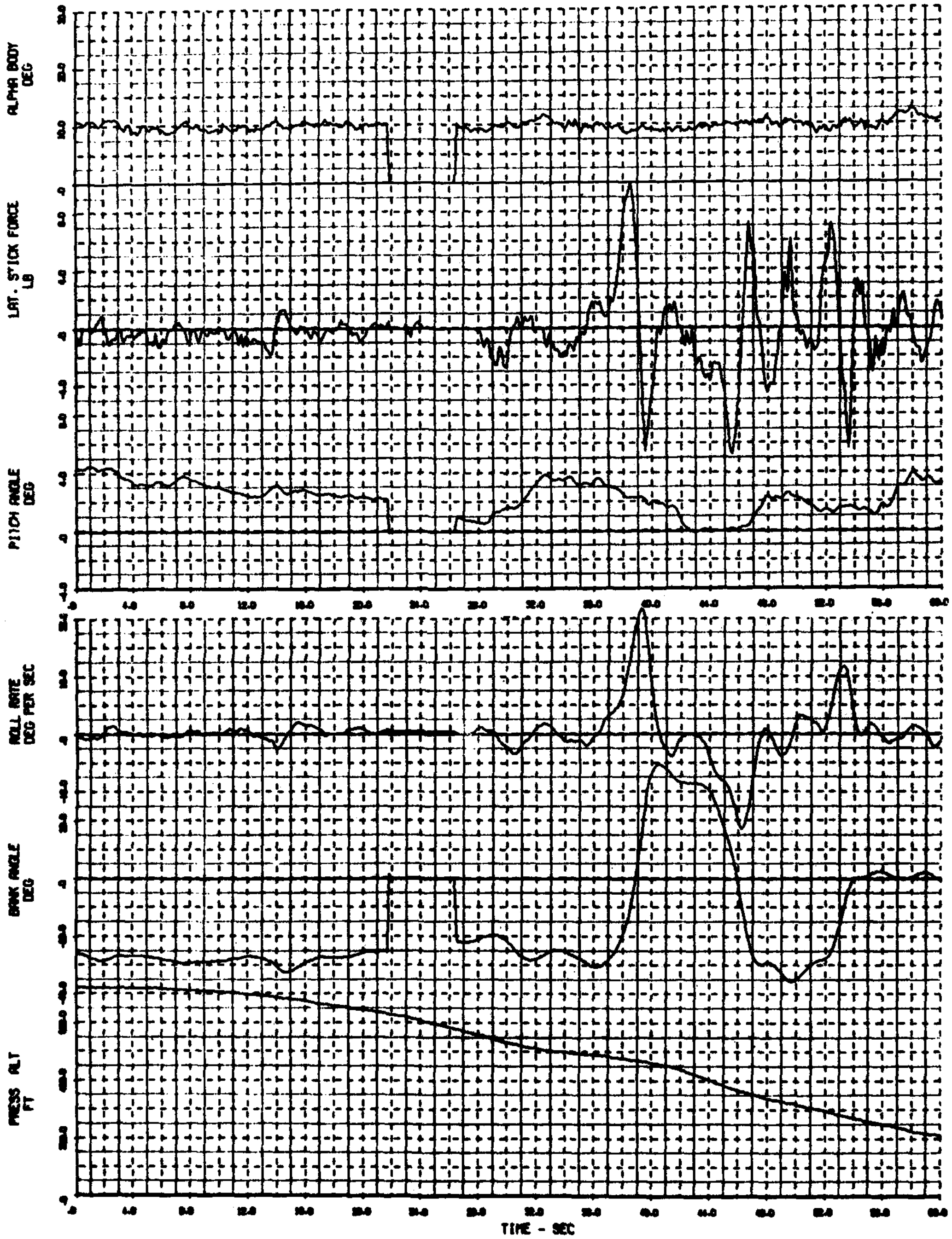


GP13-0884-116

Figure E-39b. Flight Characteristics - Roll Rate Response

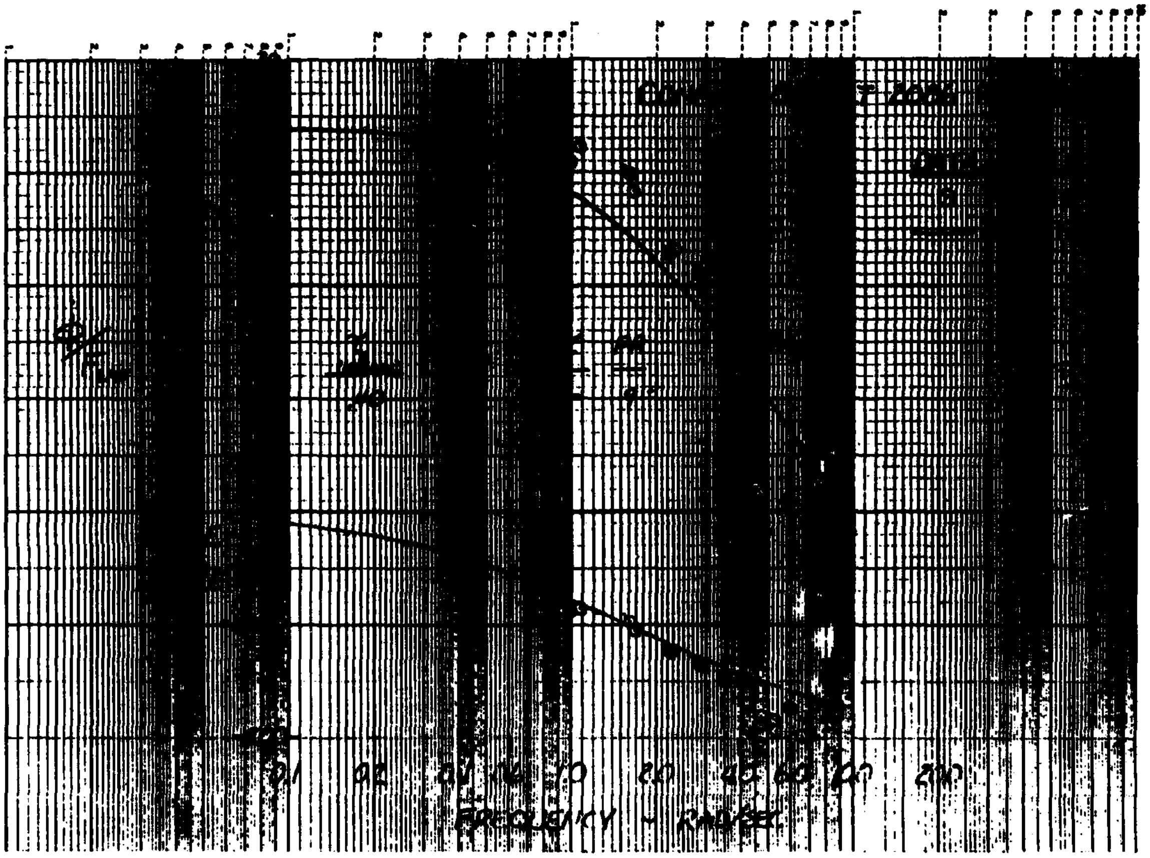
CONFIG L8B - LANDING NO. 2 FLT 2086 REC NO. 21

Pilot A; PR 9



GP13-0884-117

Figure E-40a. Flight Characteristics - Time History

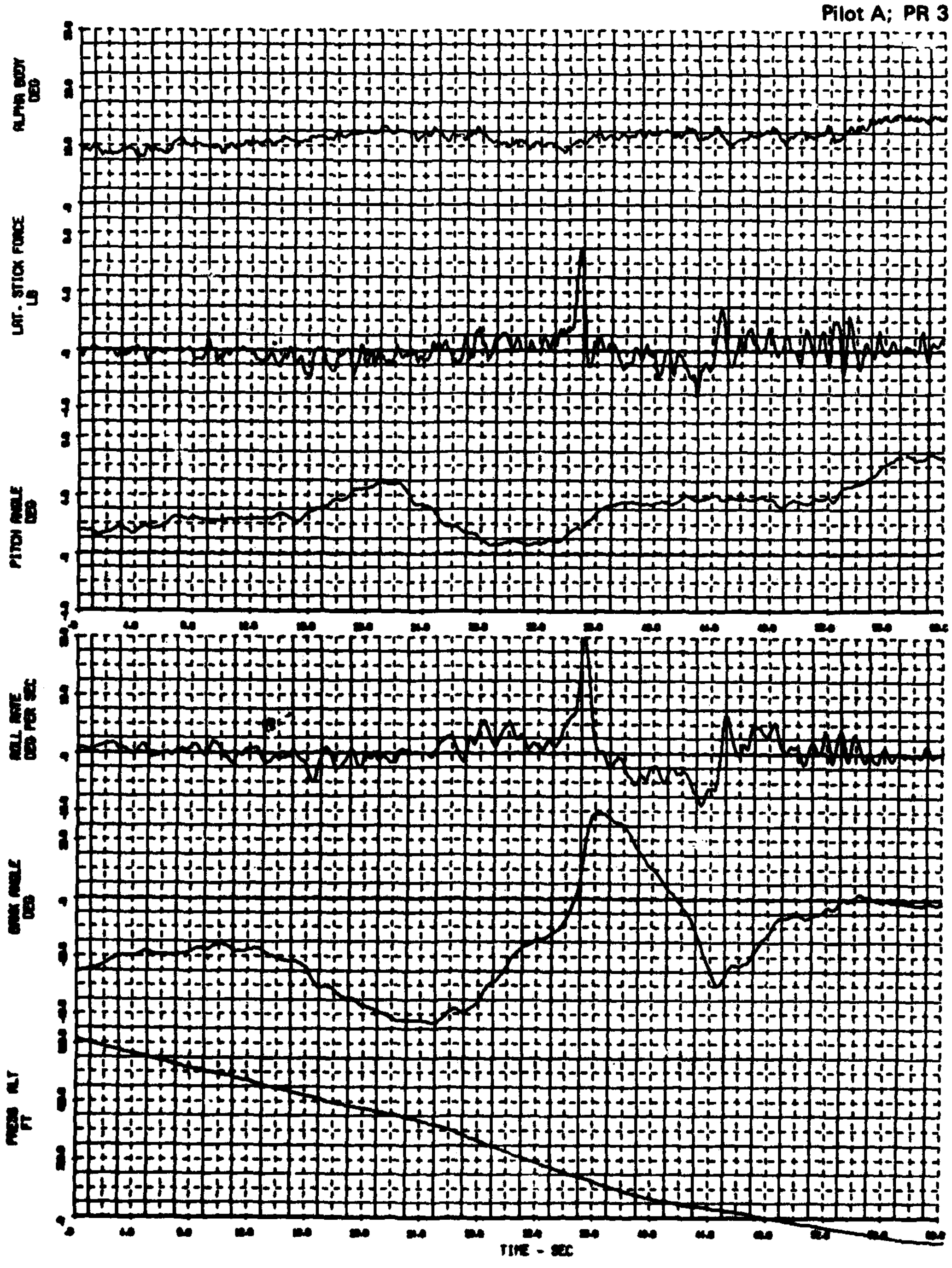


GP13-0024-118

Figure E-40b. Flight Characteristics - Roll Rate Response

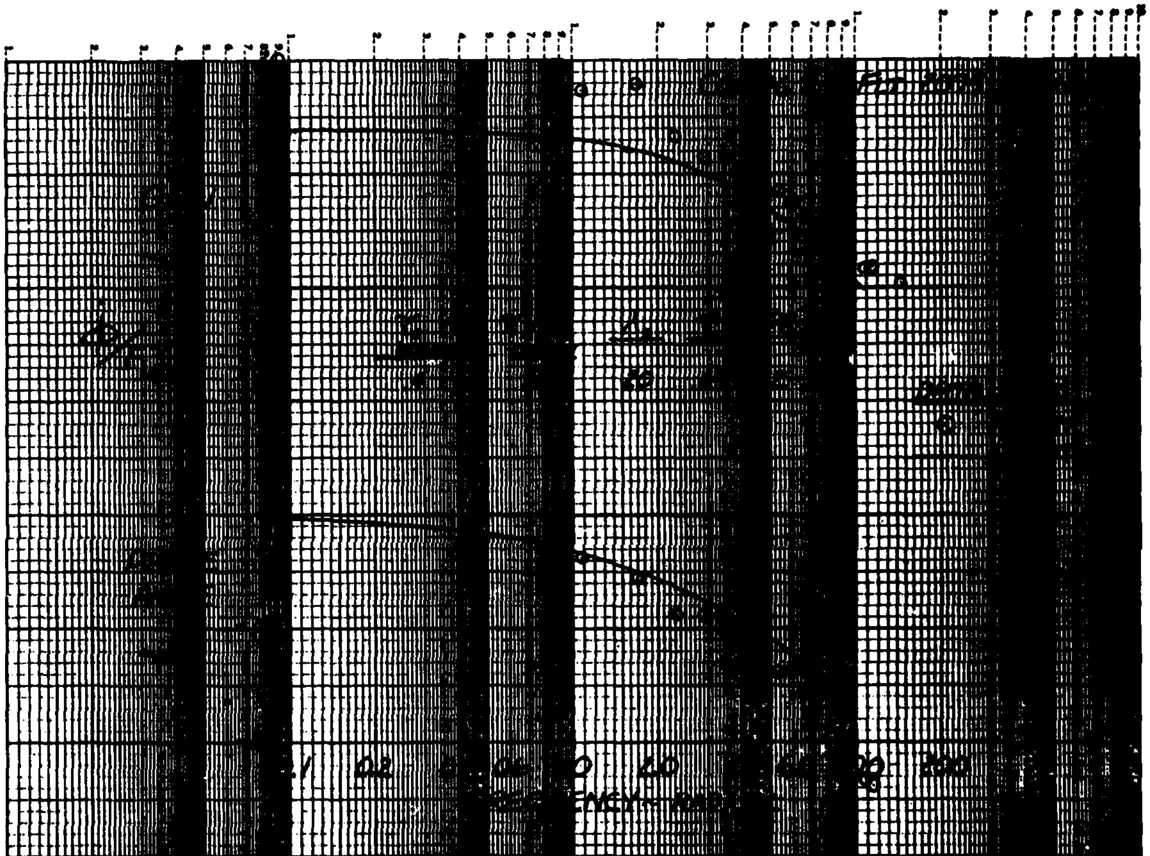
CONFIG L9 -LANDING NO. 3 FLT 2079 REC NO. 10

Pilot A; PR 3



GP13-0804-118

Figure E-41a. Flight Characteristics - Time History

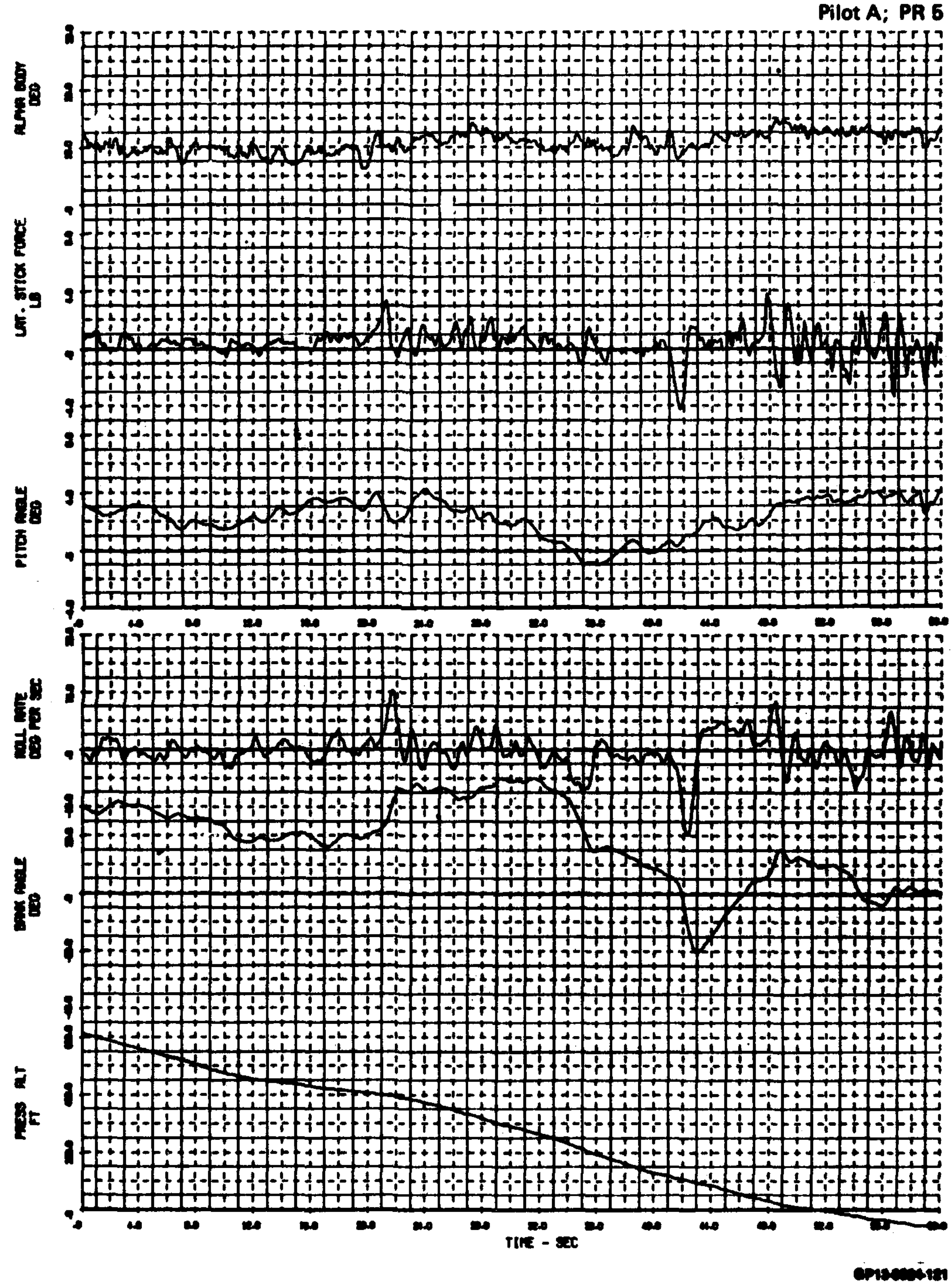


GP13-0224-129

Figure E-41b. Flight Characteristics - Roll Rate Response

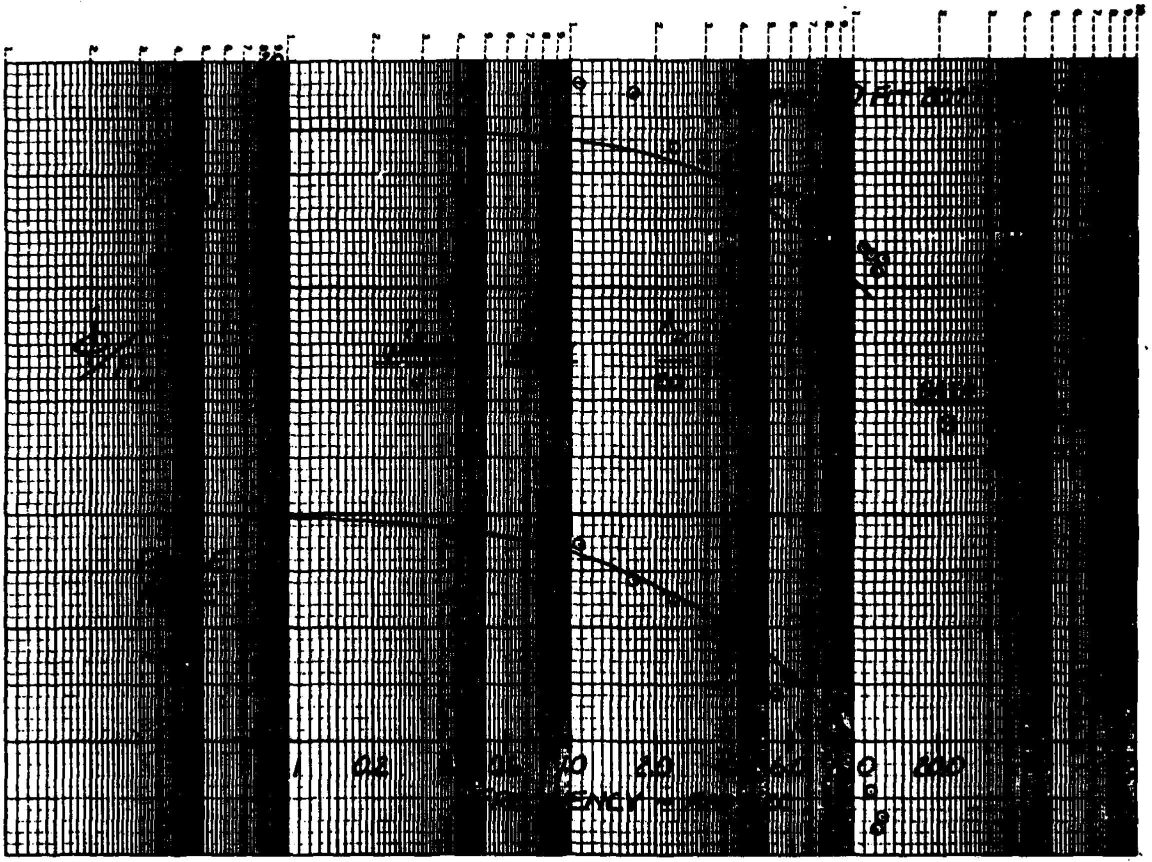
CONFIG L10 -LANDING NO. 2 FLT 2077 REC NO. 17

Pilot A; PR 5



GP13-0684-121

Figure E-42a. Flight Characteristics - Time History

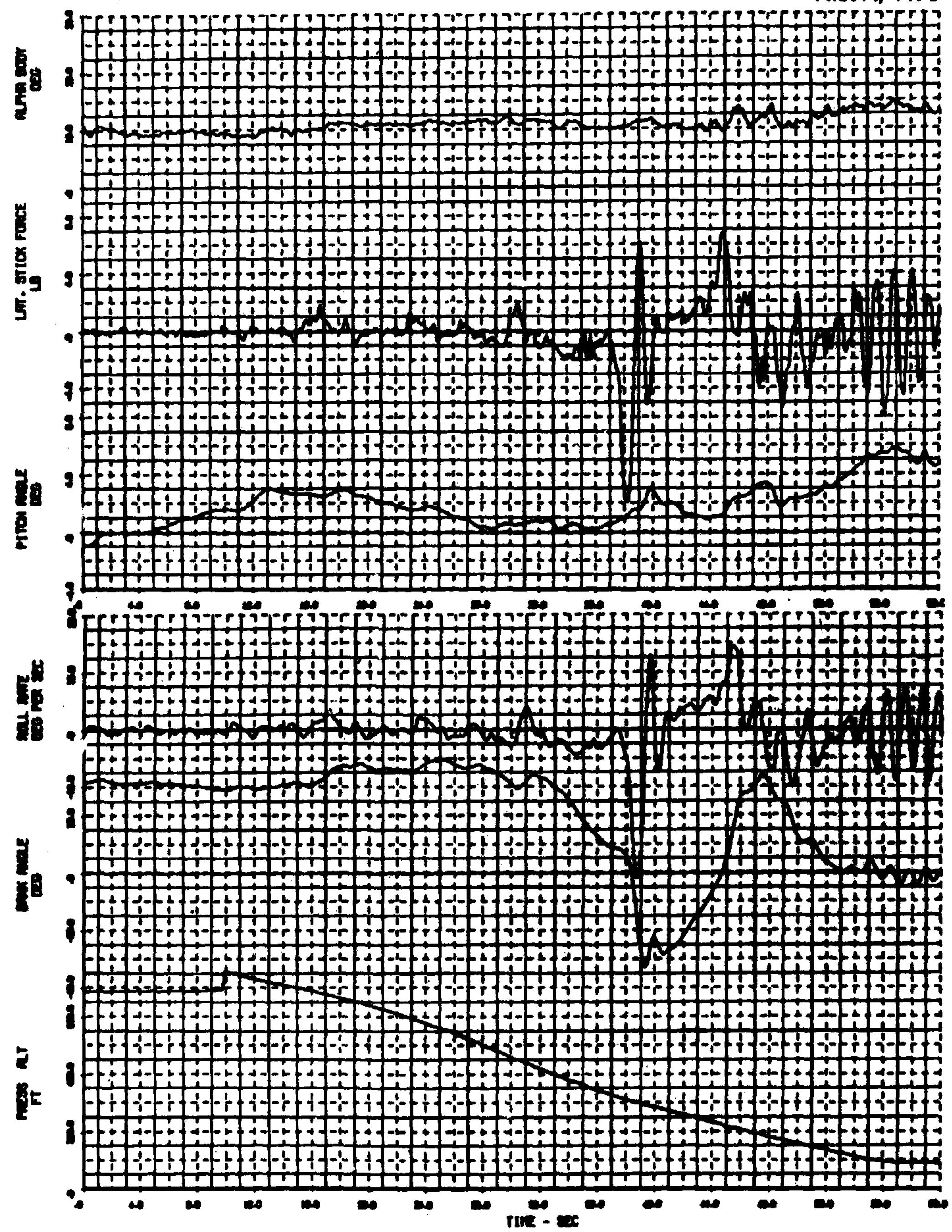


GP13-0334-122

Figure E-42b. Flight Characteristics - Roll Rate Response

CONFIG L11C - LANDING NO. 2 FLT 2083 REC NO. 15

Pilot A; PR 9



GP10-0024-139

Figure E-43a. Flight Characteristics - Time History

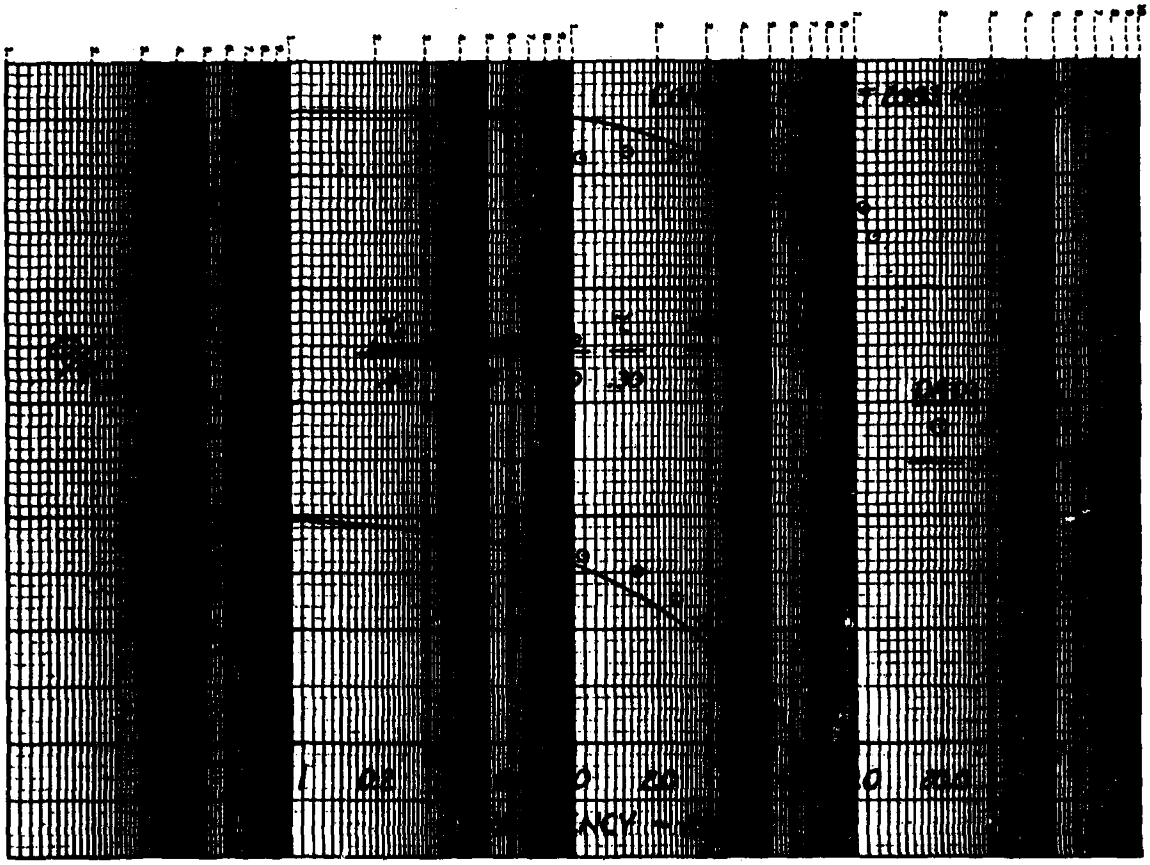


Figure E-43b. Flight Characteristics - Roll Rate Response

CONFIG L11D-LANDING NO. 1 FLT 2078 REC NO. 7

Pilot A; PR 10

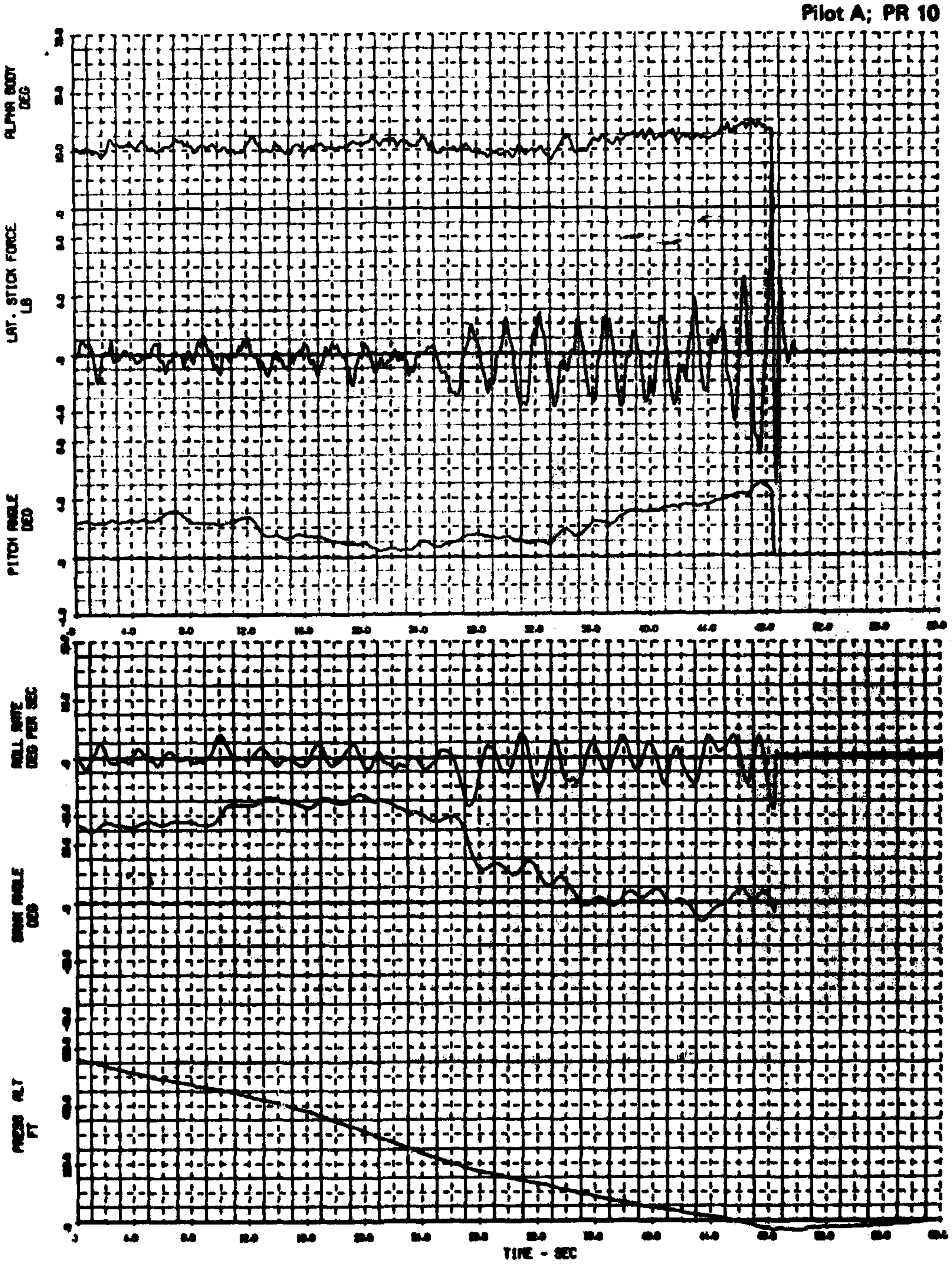
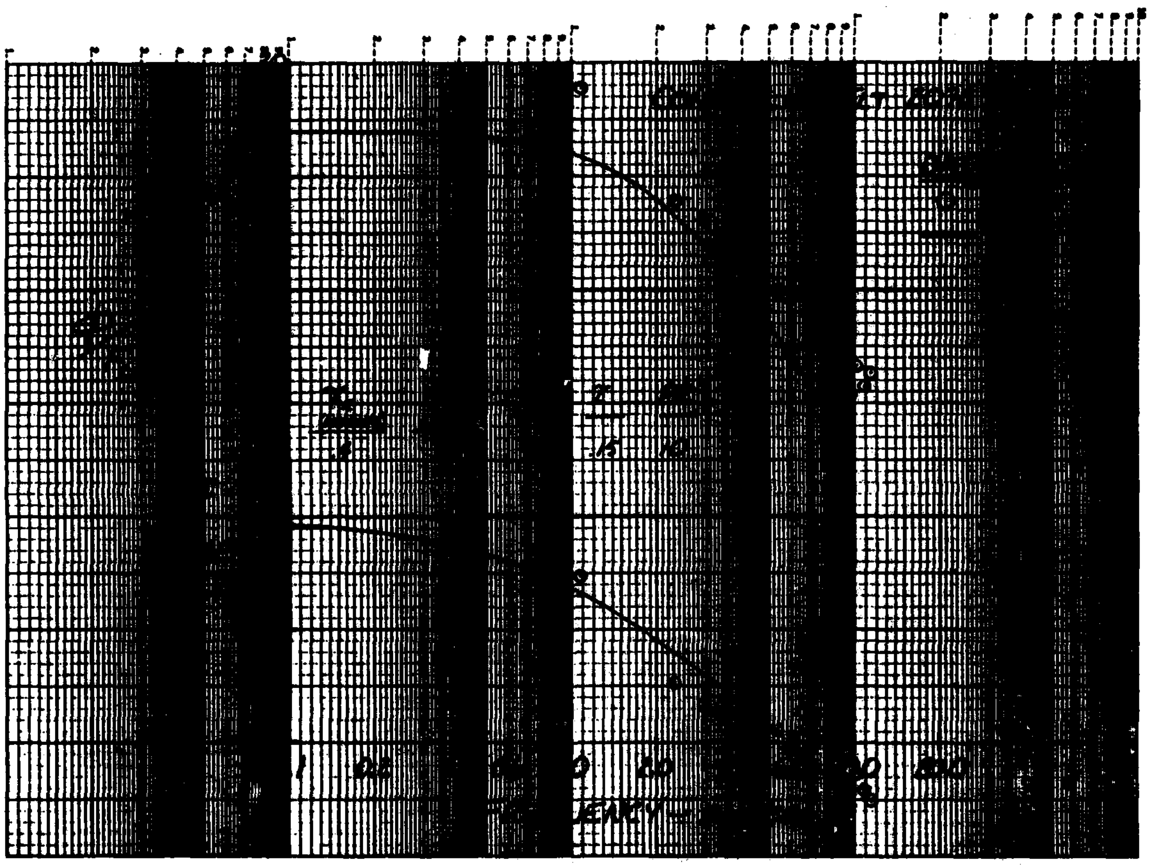


Figure E-44a. Flight Characteristics - Time History



GP13-0824-126

Figure E-44b. Flight Characteristics - Roll Rate Response

CONFIG L14-1- LANDING NO. 2 FLT 2080 REC NO. 2

Pilot A; PR 5

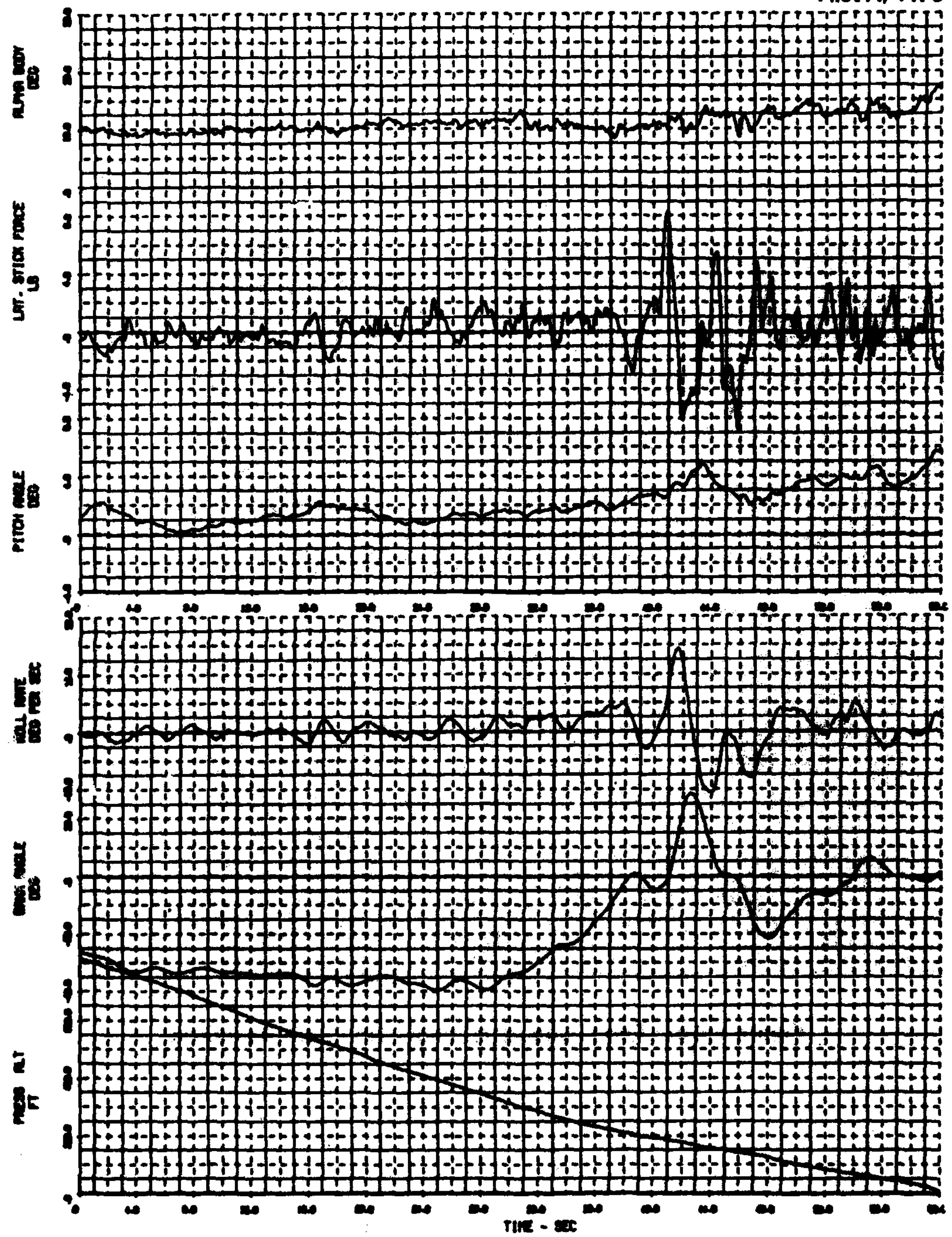


Figure E-45a. Flight Characteristics - Time History

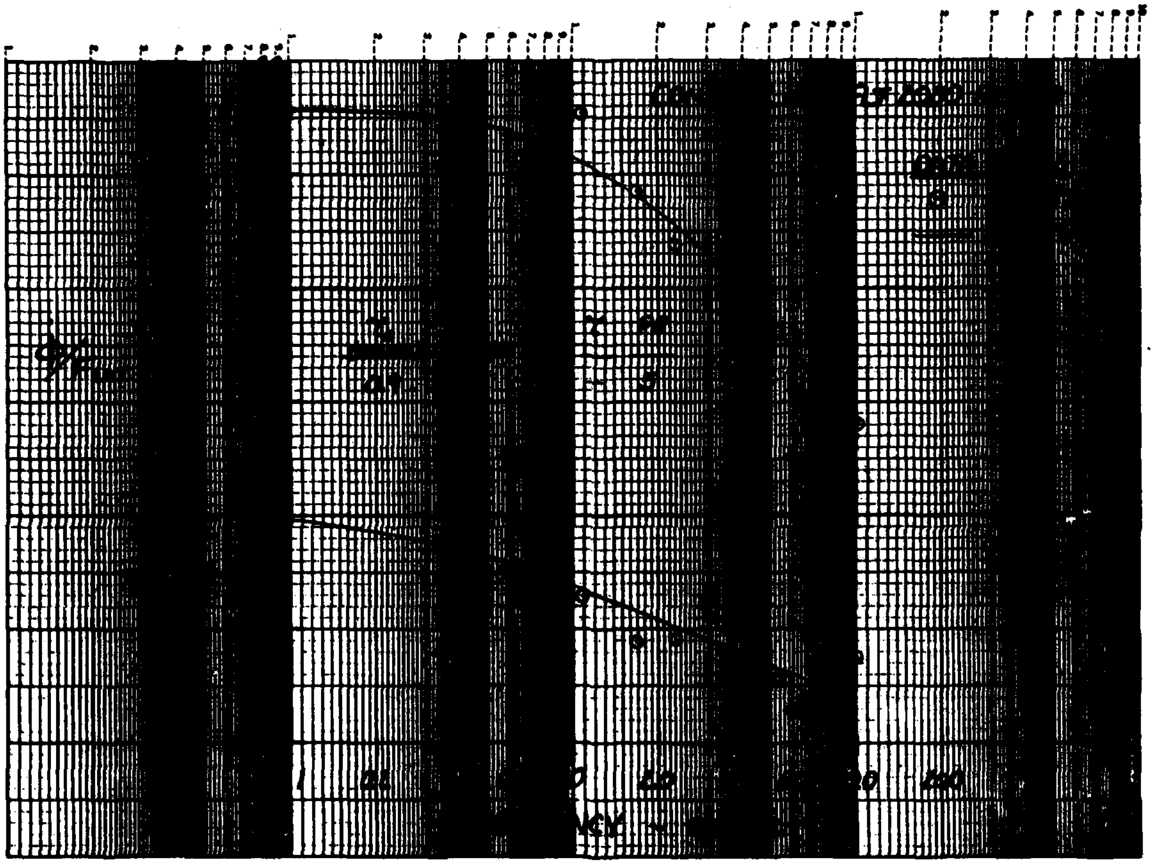


Figure E-46b. Flight Characteristics - Roll Rate Response

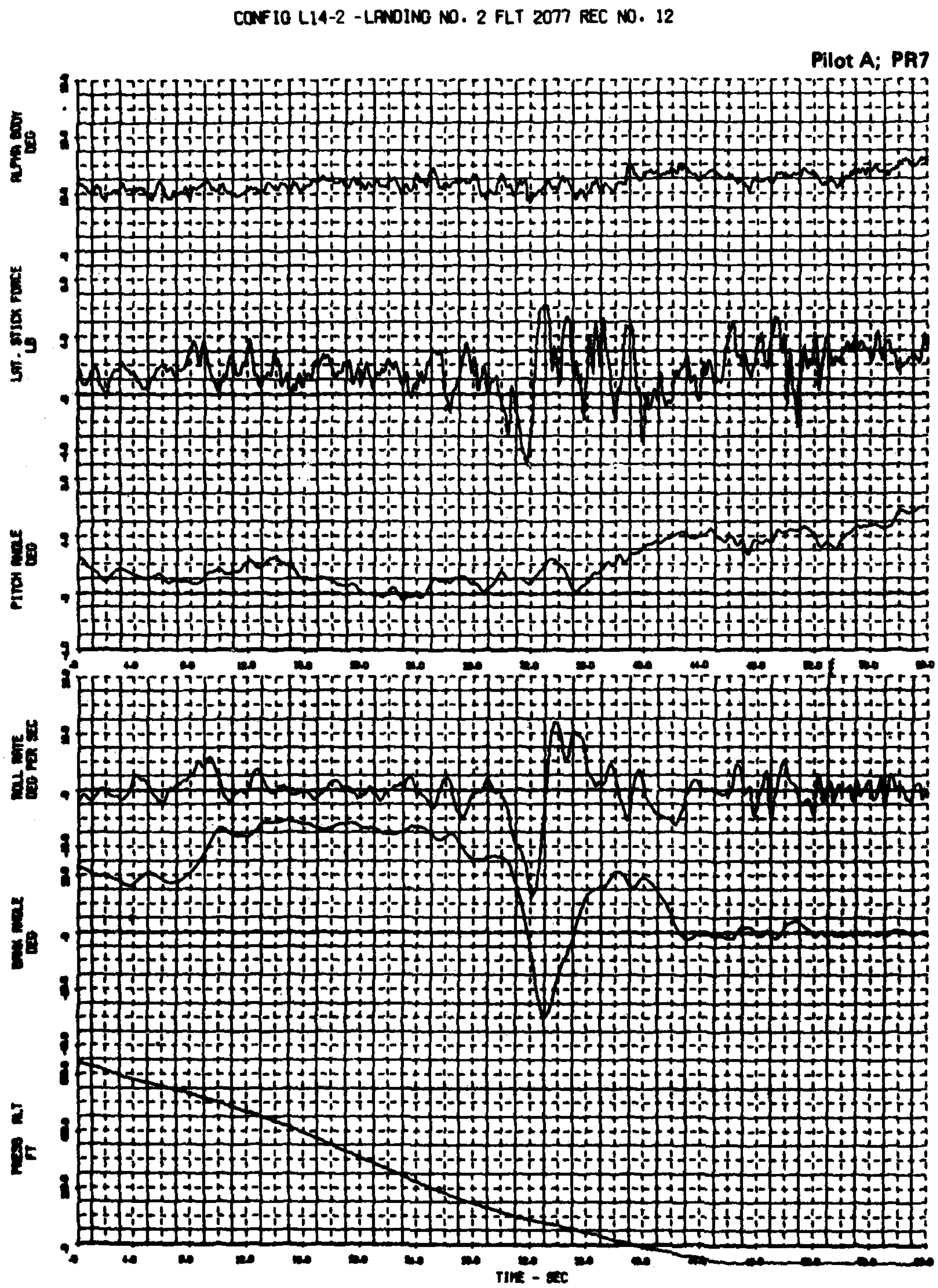


Figure E-46a. Flight Characteristics - Time History

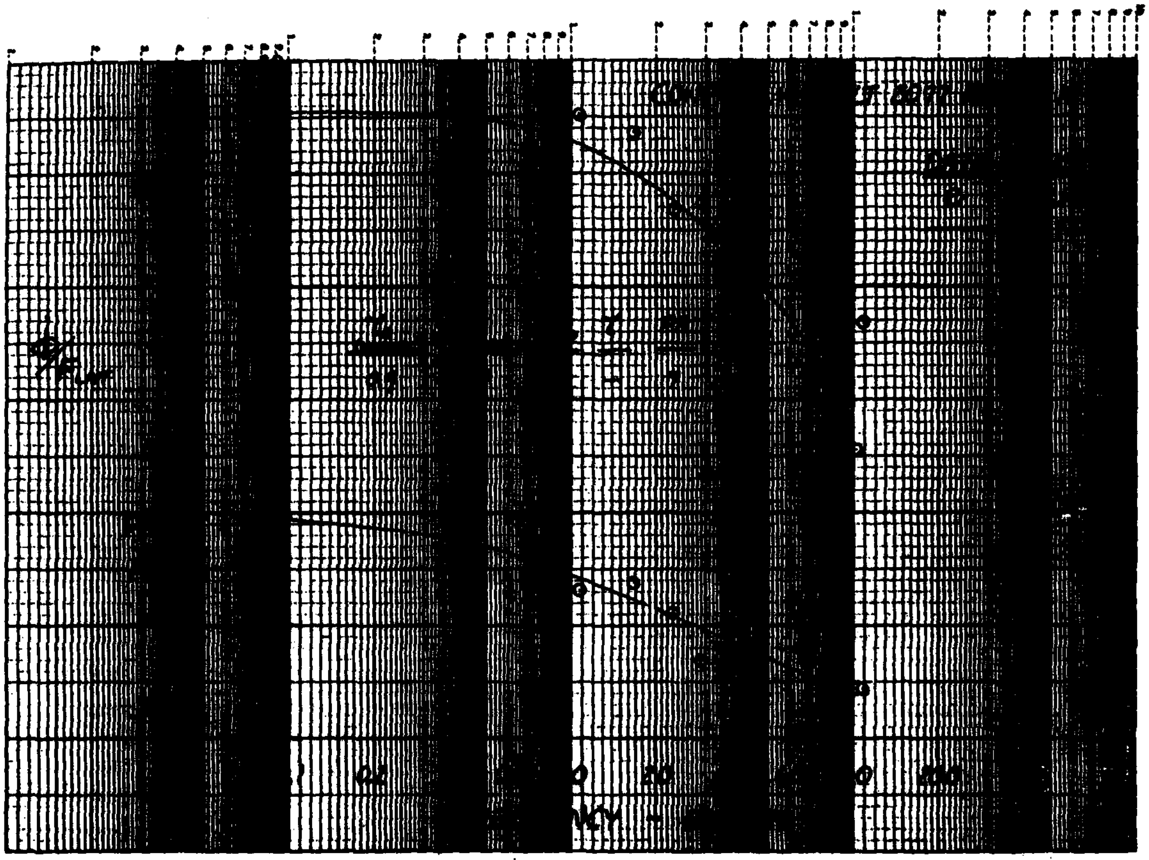


Figure E-46b. Flight Characteristics - Roll Rate Response

CONFIG L14B - LANDING NO. 2 FLT 2083 REC NO. 4

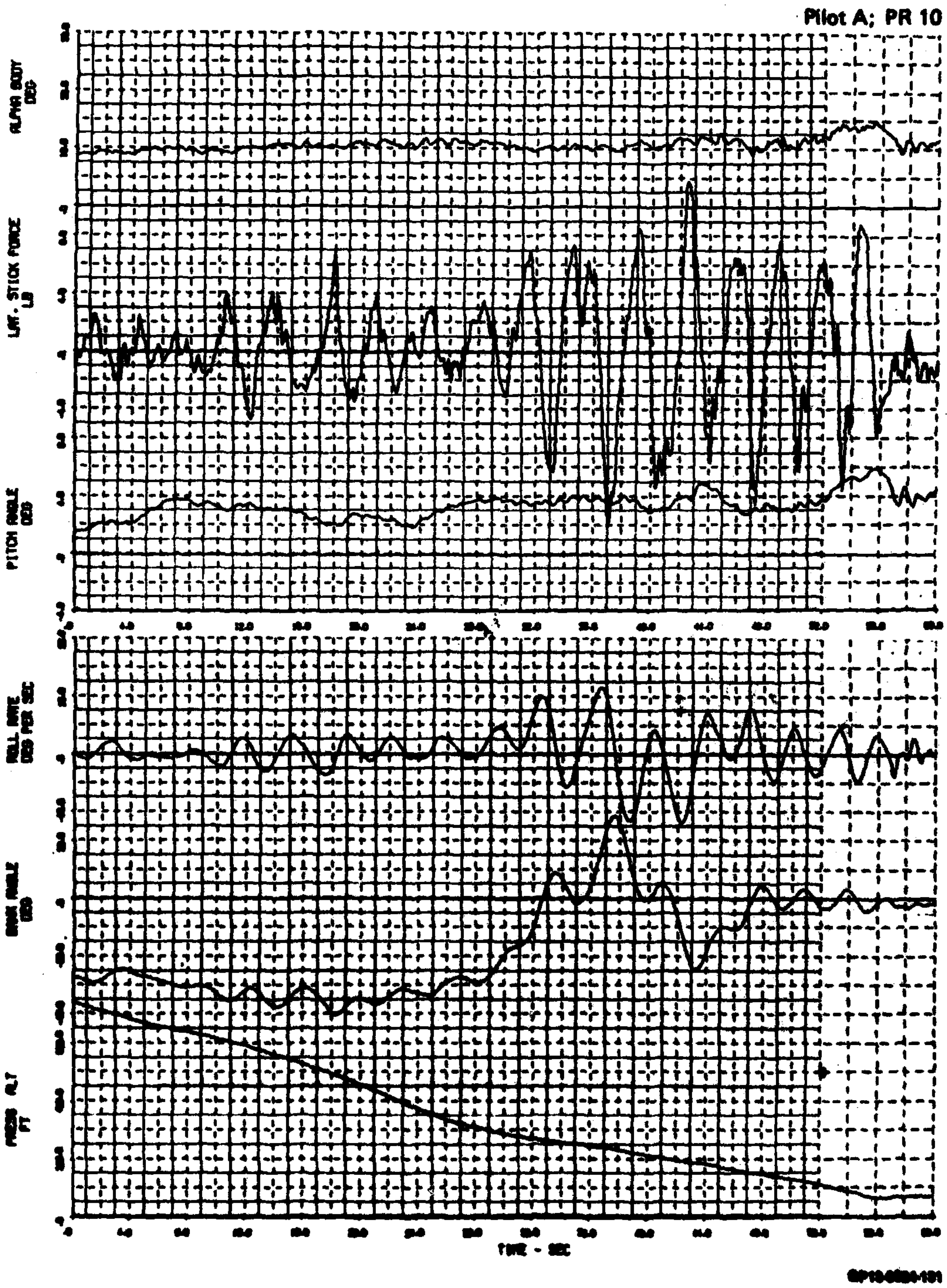


Figure E-47a. Flight Characteristics - Time History

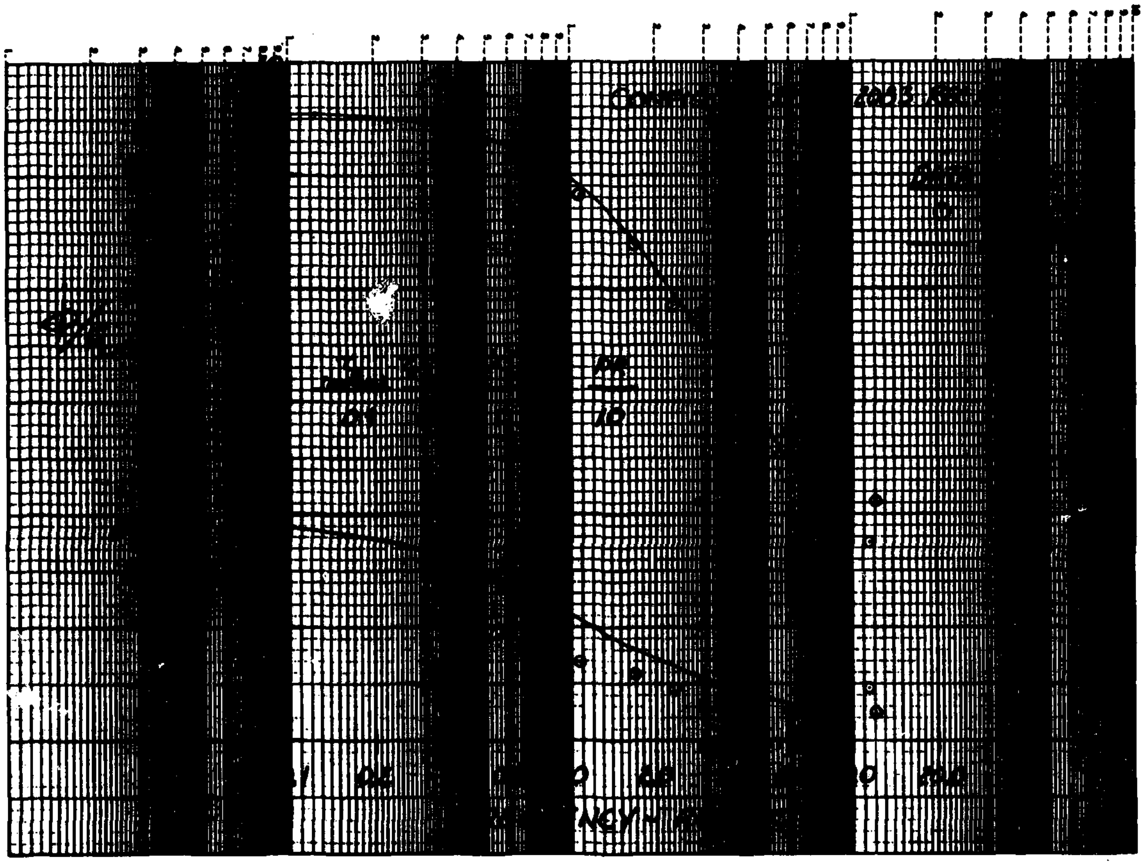


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Figure E-47b. Flight Characteristics - Roll Rate Response

CONFIG L16A - LANDING NO. 2 FLT 2080 REC NO. 14

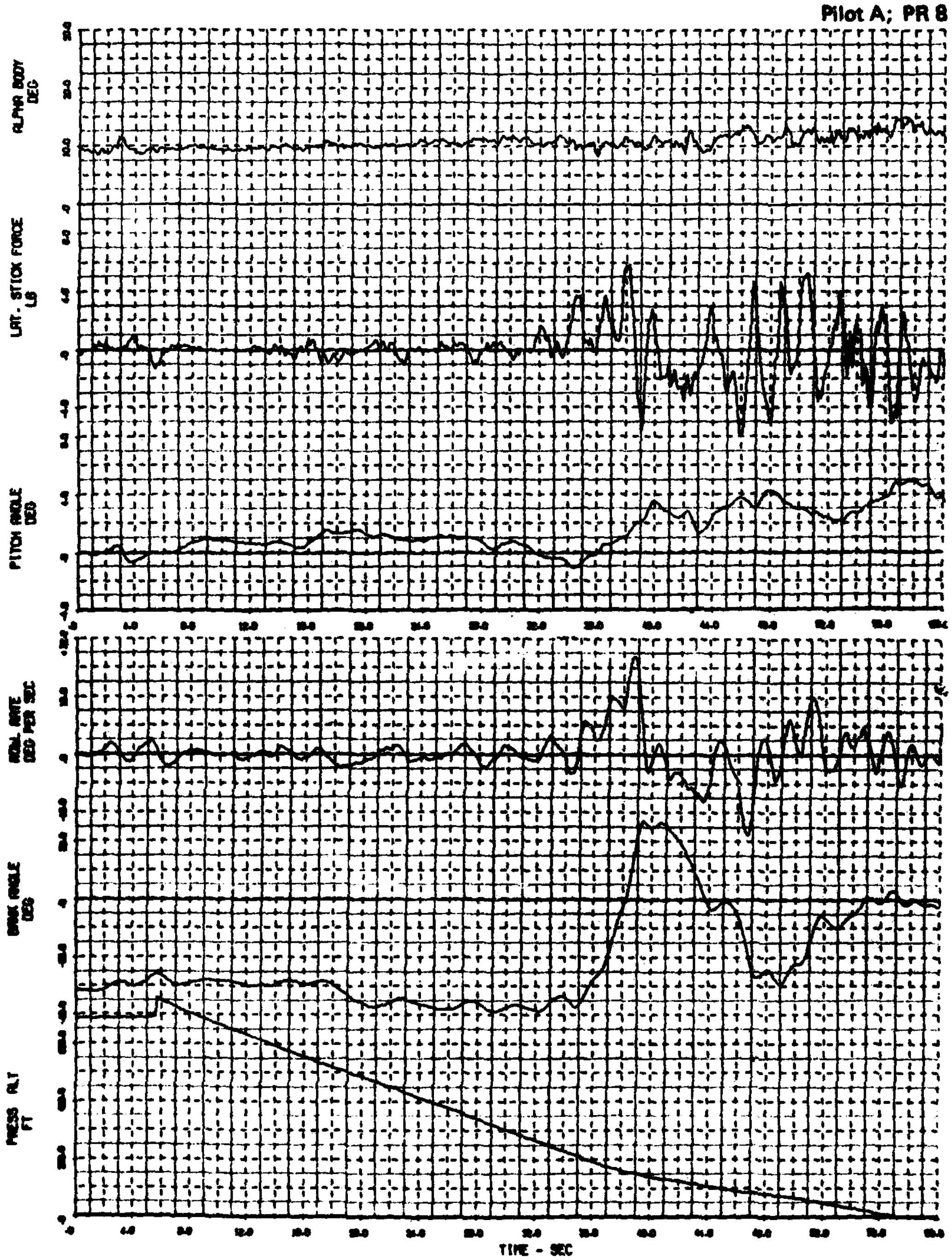


Figure E-46a. Flight Characteristics - Time History

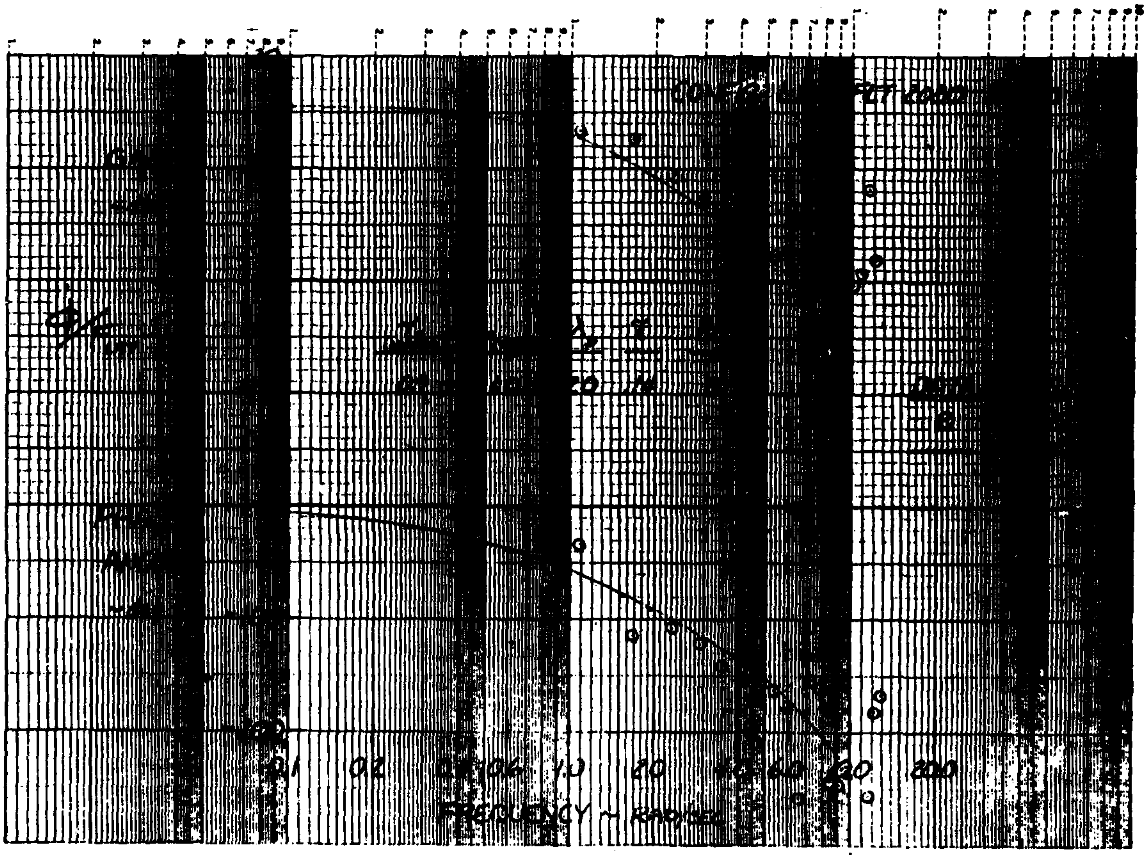


Figure E-48b. Flight Characteristics - Roll Rate Response

APPENDIX F

APPLICATION OF NEAL AND SMITH'S CRITERION

The Neal and Smith closed-loop analysis technique (Ref 3) was applied to the Equivalent System Program data. For the longitudinal set of dynamics, bandwidth variations were made to obtain the best correlation with the previously established flying qualities level boundaries. The lateral set of dynamics from the data were also analyzed and correlations were attempted.

Longitudinal Analysis

A paper pilot was added to the airframe dynamics of the configurations in the equivalent systems program (Table 5, Section VI) to find if the Neal and Smith criterion for pilot rating boundaries shows a correlation with the pilot ratings from the flight evaluations. The procedure was to assume bandwith (frequency at which the closed-loop phase, θ/θ_C, is -90 degrees) and plot the pitch resonance and corresponding phase margins for ESP configurations. The paper pilot time delay was held at 0.3 seconds. Figures F-1a through F-1d show the variation in pitch resonance and required pilot compensation at various values of bandwidth. Sixteen configurations were used with bandwidth varying from 0.5 to 3.5 rad/sec. As bandwidth increases, the data tends to move from negative to positive (i.e. lag to lead) pilot compensation with essentially zero resonance. As pilot compensation nears 90 , resonance increases sharply. Associated with this migration is a tendency for the data to scatter as bandwidth increases. A bandwidth of 2.5 rad/sec appears to give the best correlation, Figure F-1c.

Figures F-2a and 2b show a comparison of high-order systems (HOS) and low-order systems (LOS) in terms of the Neal and Smith criteria. These were made at a bandwidth of 2.5 rad/sec. Good correlation exists for all HOS/LOS comparisons except for the resonance values of P15/P16 and P15/P17. Thus, high-order systems and their low-order counterparts have the same characteristics by the Neal and Smith criterion, except that the HOS resonance exceeded LOS values for the PIO-prone cases. Time history data in Appendix E verify this.

Previous analysis has shown the importance of equivalant time delay (Ref 11) and the use of lead/lag prefilters to reduce the effects of high frequency phase lags is discussed in longitudinal results Section VI-2. of this report. Figure F-3 presents the Neal and Smith criterion interpretation of these elements. Increasing time delay for a given configuration increases both resonance and required pilot lead compensation. However, Neal and Smith predicts the entire time delay investigation with Configuration P10A-D and P12 as having Level 2 flying qualities, whereas the actual Pilot ratings go from 2 (at $\tau = 0$) to 8 (at $\tau = .20$ seconds). For the lead/lag filters, Neal and Smith criterion

correctly interprets the addition of these filters as reducing the amount of pilot lead compensation required. Again, while all three configurations have Level 3 flying qualities, the criterion predicts Level 2.

Lateral Analysis

Bandwidths of 0.5 to 2.5 rad/sec were studied for the lateral dynamics. Figures F-4a through 4d show the variation in resonance and pilot compensation with bandwidth, and no bandwidth correlation was possible.

Figure F-5 shows a comparison of resonance and pilot compensation between HOS's and LOS's. A bandwidth of 2.5 rad/sec was used to correspond with the value used for longitudinal dynamics. It should be noted that the lateral experiment included only L1/L2 and L3/L4 as equivalent high-order versus low-order systems. The balance of the lateral ESP configurations dealt with variations in control system lag and time delay effects. A few pseudo "high-order" versus low-order systems are available for comparison: L6/L4, L6/L9. Again, for the most part the Neal and Smith criterion shows the same characteristics for the high order systems and their counterpart low order systems.

In summary the Neal and Smith closed-loop criterion gave fair correlation for the longitudinal dynamics at a bandwidth of 2.5 rad/sec. However, correlation was not possible at any bandwidth for lateral dynamics. With a few exceptions, the criterion generally equated the pitch resonance and pilot compensation for high versus low order systems, both longitudinally and laterally.

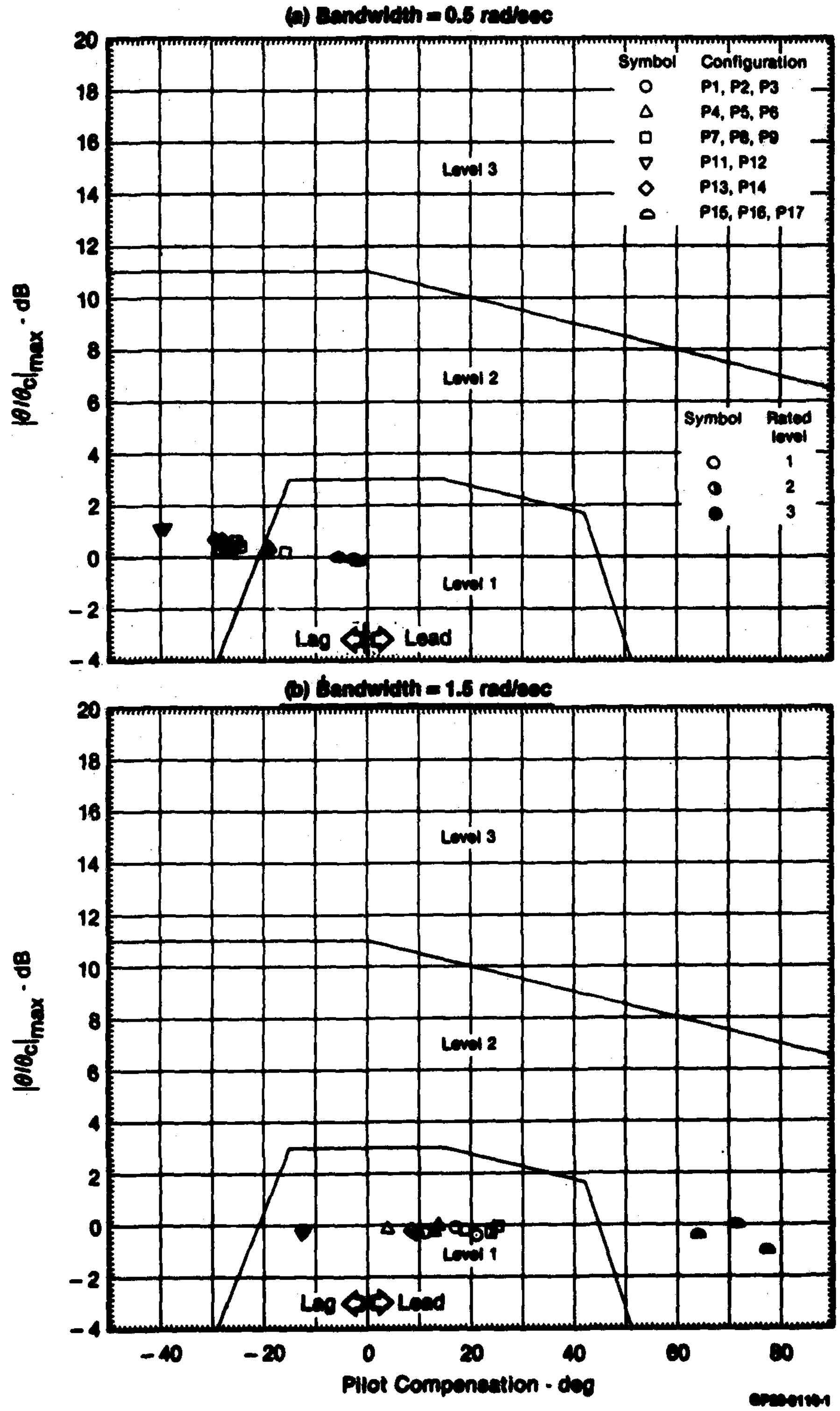


Figure F-1. Variation of Pilot Compensation and Resonance with Bandwidth Longitudinal Dynamics

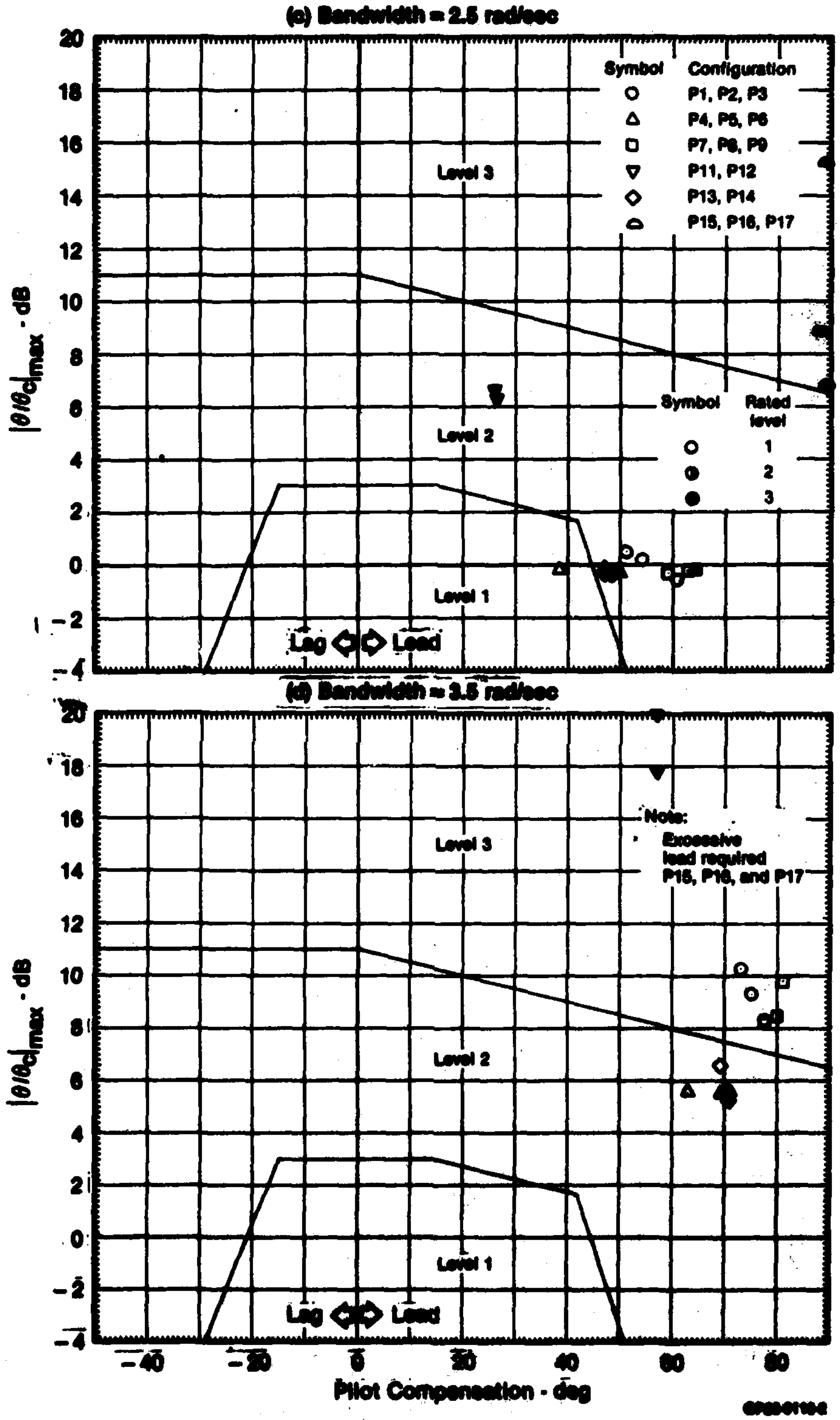


Figure F-1 (Continued). Variation of Pilot Compensation and Resonance with Bandwidth Longitudinal Dynamics

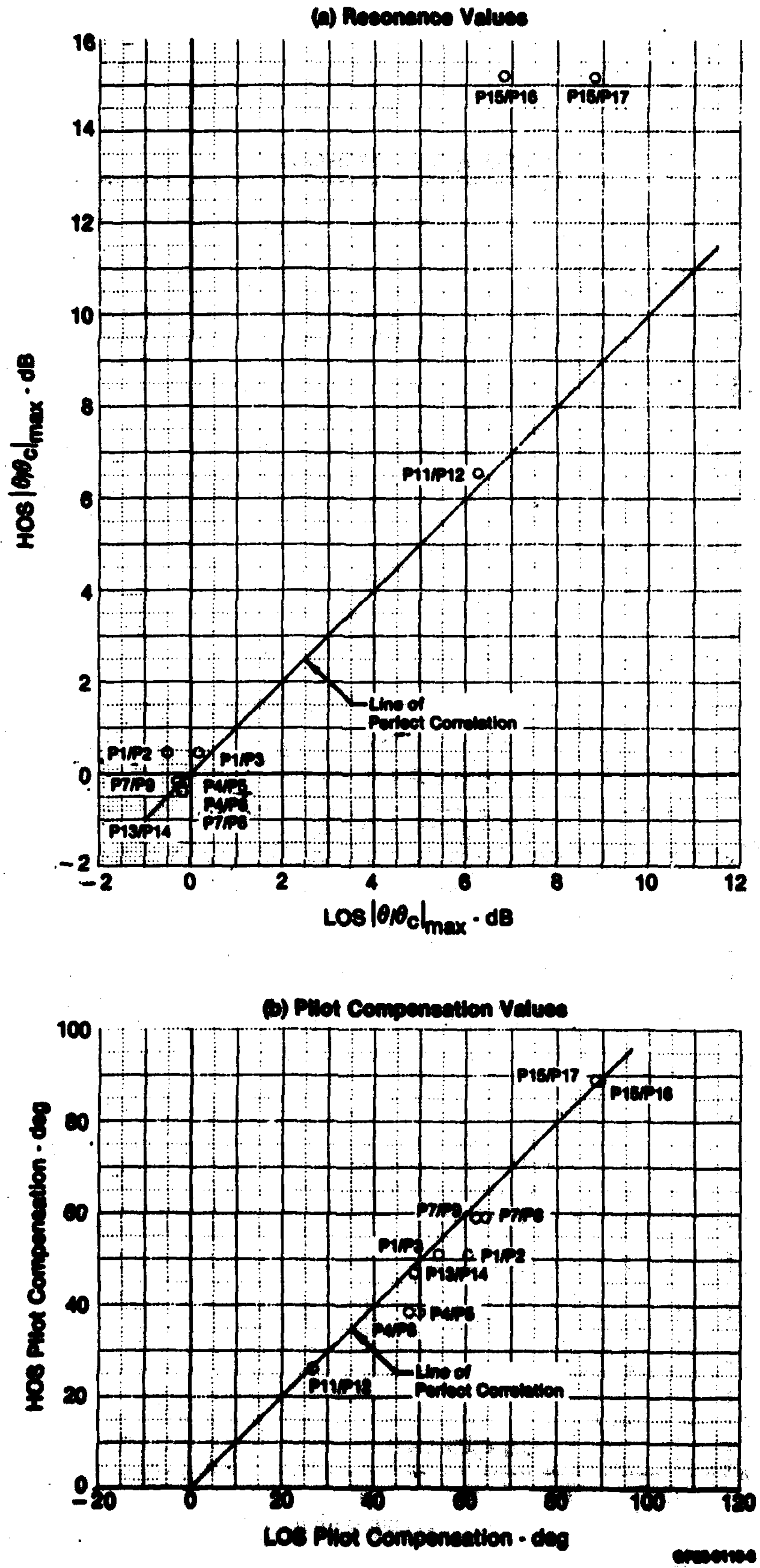


Figure F-2. Comparison of Resonance Values and Pilot Compensation Values for HOS vs LOS
ESP Longitudinal Dynamics Bandwidth = 2.5 rad/sec

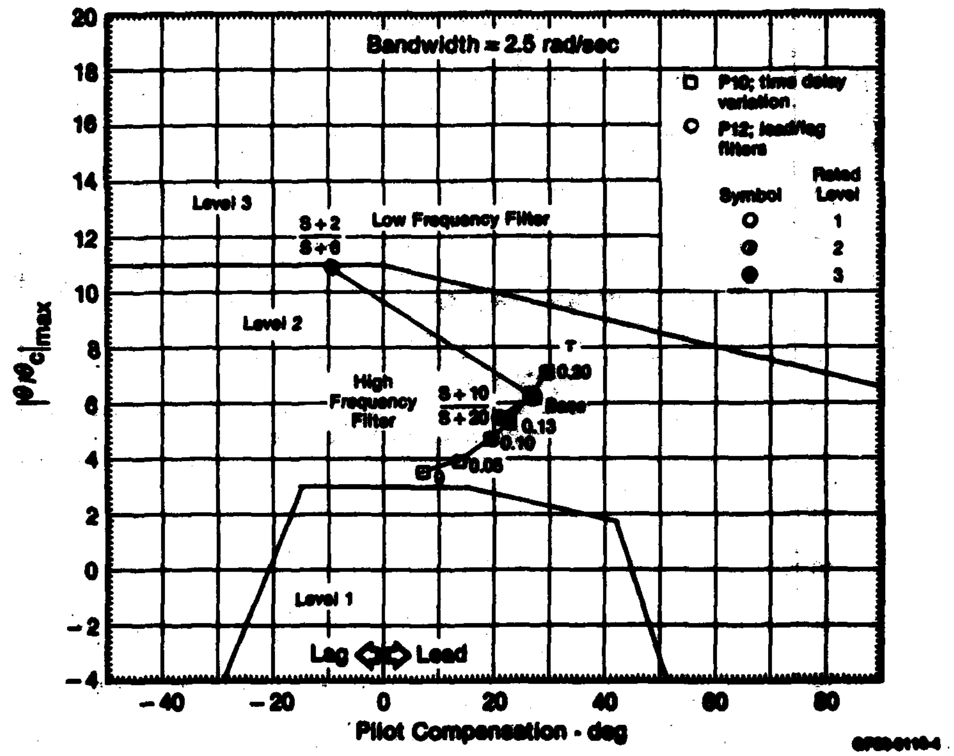


Figure F-3. Effect of Time Delay and Lead/Lag Filters on the Neal and Smith Plane ESP Longitudinal Dynamics

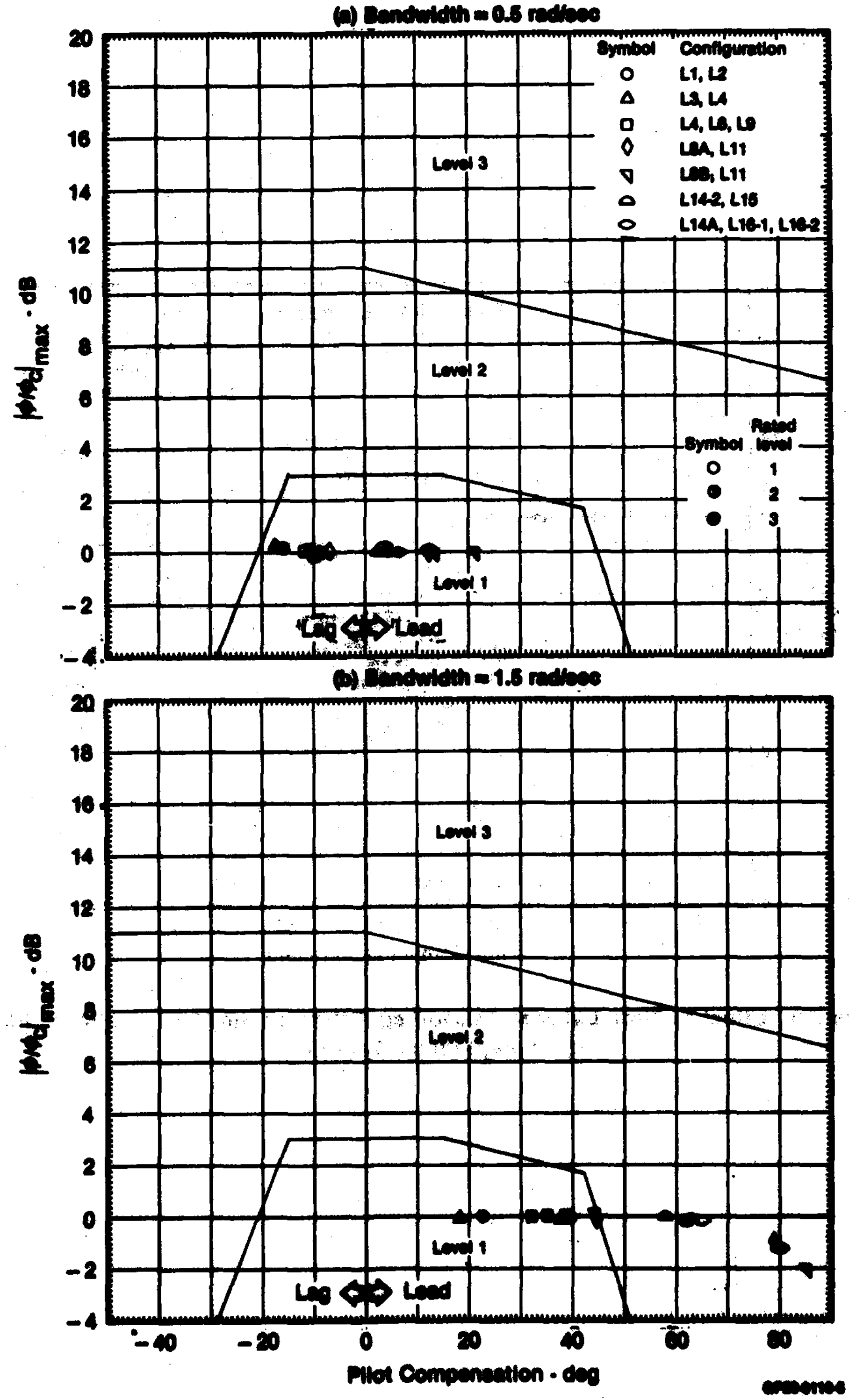


Figure F-4. Variation of Pilot Compensation and Resonance with Bandwidth Lateral Dynamics

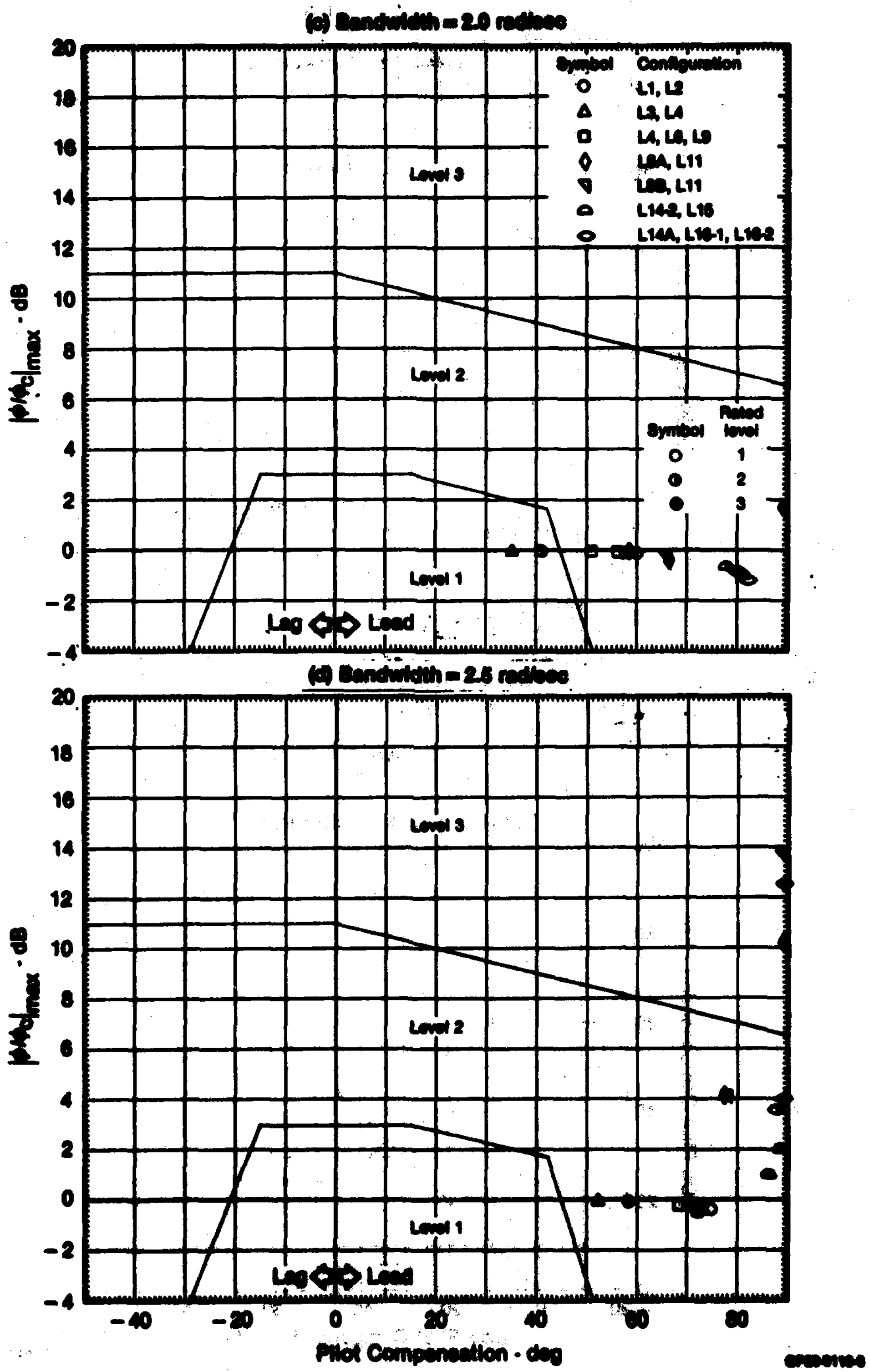


Figure F-4 (Continued). Variation of Pilot Compensation and Resonance with Bandwidth Lateral Dynamics

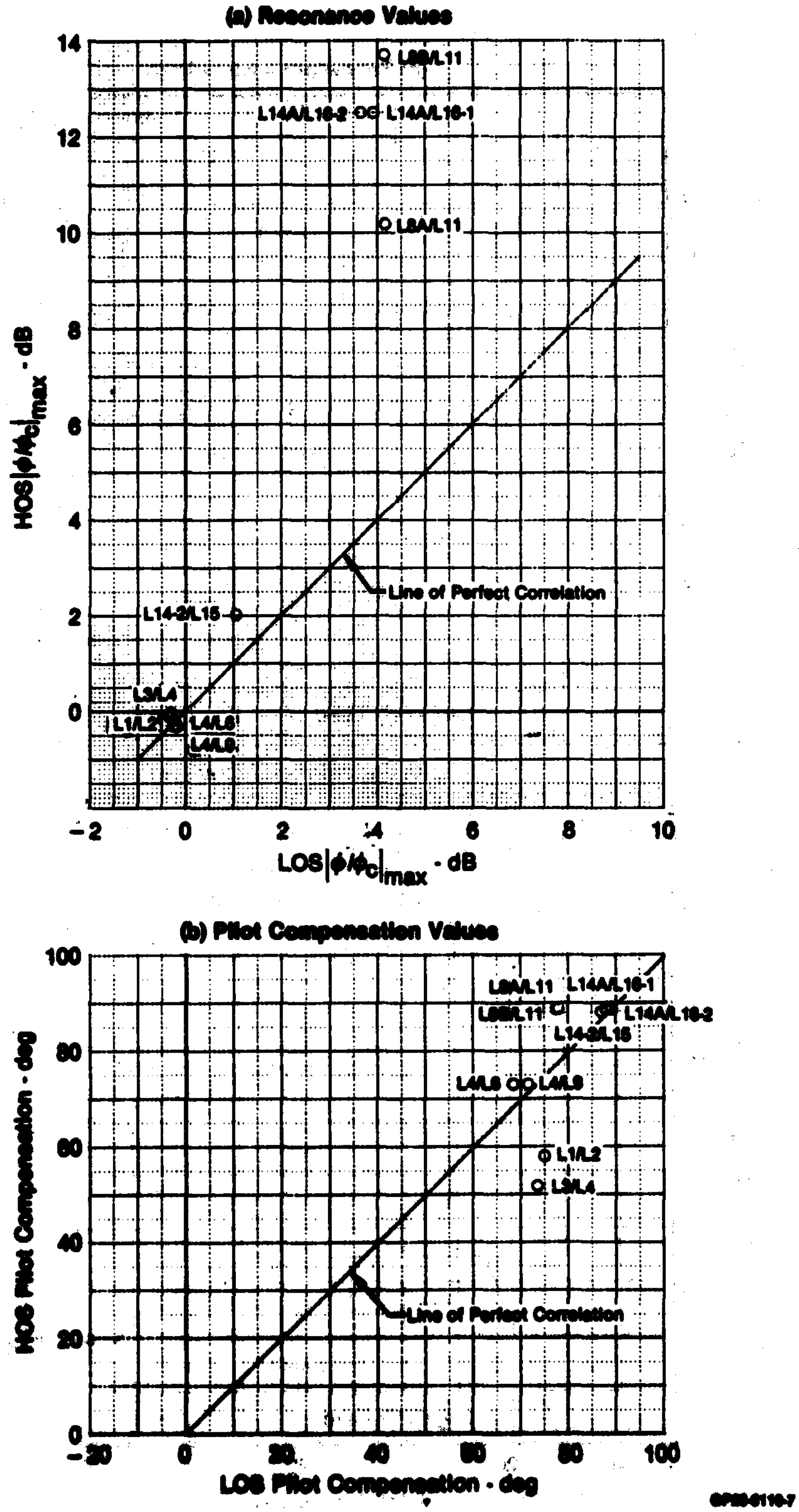


Figure F-6. Comparison of Resonance Values and Pilot Compensation Values for HOS vs LOS
ESP Lateral Dynamics Bandwidth = 2.5 rad/sec

DEVELOPMENT OF CORRELATIONS BETWEEN NEAL AND SMITH'S CLOSED-LOOP ANALYSIS TECHNIQUE AND EQUIVALENT SYSTEM MODELING

A study was made to compare the Neal and Smith closed loop flying qualities analysis technique with equivalent system modeling. The Neal and Smith techniques was applied at a bandwidth of 2.5 rad/sec and a pilots time delay of 0.3 sec. The LAHOS data of Reference 4 were chosen to establish values for correlation coefficients for the relationships of combinations and variations of typical parameters in the longitudinal ESP data.

L_α Fixed Comparisons

Different combinations and variations of pilot compensation (PC), resonance ($|\frac{\theta}{\theta_c}|_{max}$), equivalent short period frequency (ζ_{sp_e}), and equivalent short period damping (ζ_{sp_e}) of the L_α fixed equivalent systems were compared to determine any correlations. It was discovered that a strong relationship exists between PC and ω_{sp_e} and between $|\frac{\theta}{\theta c}|_{max}$ and $1/\zeta_{sp_e}$. With simple linear regression analysis the correlation coefficients for the relationships were found to be 0.94 and 0.86, respectively.

An improvement in these correlations was possible by including time delay (τ) in the analysis. A multiple linear regression analysis yielded correlation coefficients of 0.95 and 0.93, respectively.

The relationships developed above were applied to the Equivalent System Program (ESP) data. Figure F-6 shows the comparison between the actual values versus the predicted values of these relationships (F-6(a) and (b) Pilot Compensation, F-6(c) and (d) Resonance).

L_α Free Comparisons

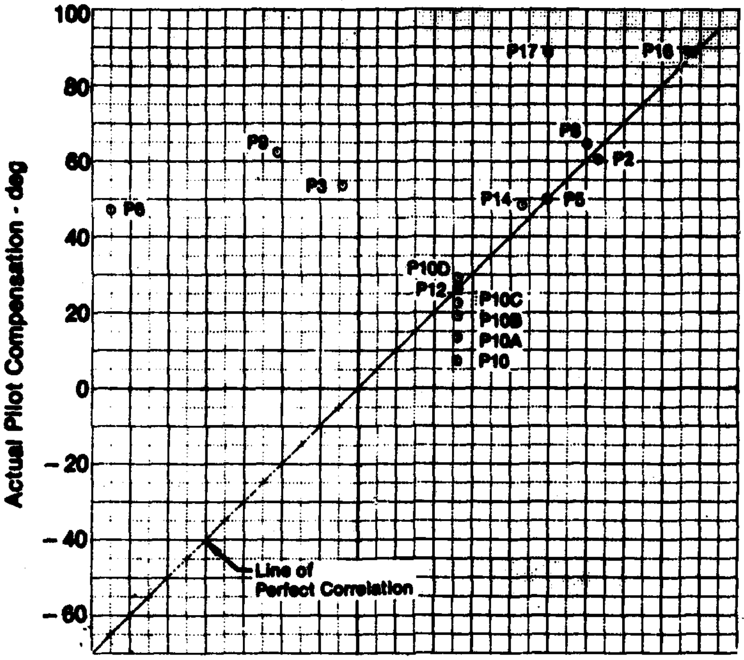
The procedure used on the L_α fixed equivalent systems was used on the L_α free equivalent systems. The best correlations were between PC and ω_{sp_e} and between $|\frac{\theta}{\theta_c}|_{max}$ and $1/\zeta_{sp_e}$, similar to the L_α fixed data. A simple linear regression was performed and correlated coefficients for the relationships were found to be 0.56 and 0.87, respectively.

An improvement in these correlatiions was possible by including τ and L_α in the analysis. A multiple linear regression analysis yielded PC as a function of ω_{sp_e}, τ, and L_α and $\left|\frac{\theta}{\theta_c}\right|_{max}$ as a function of $1/\zeta_{sp_e}$ and τ. The correlation coefficients for these relationships were found to be 0.92 and 0.89, respectively.

The relationships developed above were applied to the ESP data. Figure F-7 shows the comparison between the actual values versus the predicted values of these relationships (F-7(a) and (b) Pilot Compensation, F-7(c) and (d) Resonance).

A correlation exists between the Neal and Smith closed loop flying qualities analysis technique and equivalent system modeling for the LAHOS data. Applying these correlations to the ESP data, and comparing actual values to predicted values, indicates that these relationships are not unique to the LAHOS data. The correlations are not perfect, and further work in this area is recommended.

(a) PC = 114.2 - 33.84 ω_{sp_e}



(b) PC = 37.33 τ - 33.43 ω_{sp_e} + 107.4

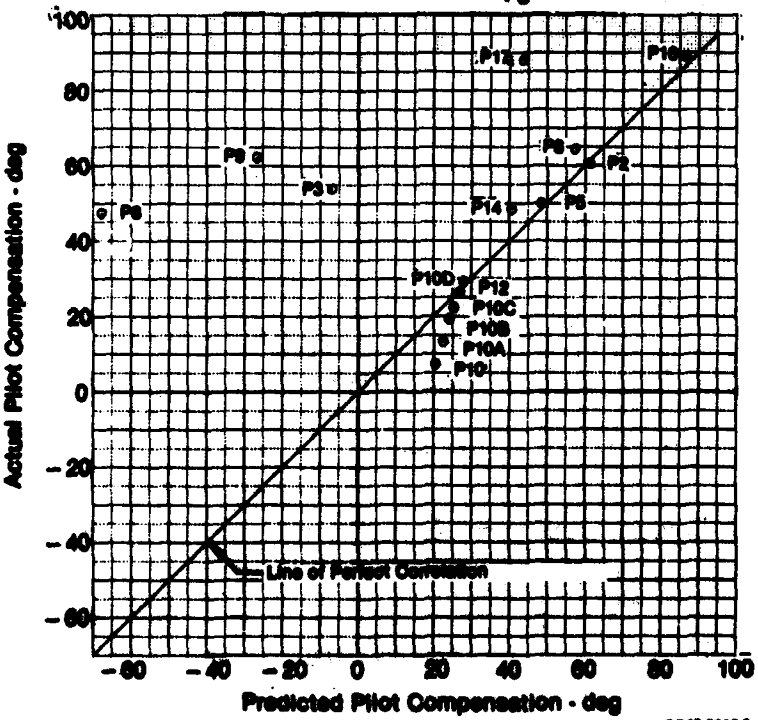
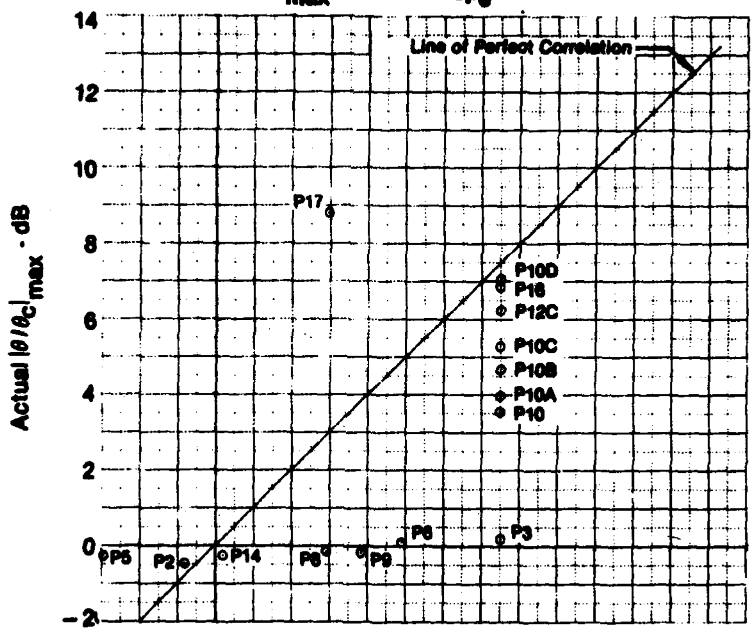


Figure F-6. Pilot Compensation - Actual vs Predicted, Longitudinal ESP Data L_α Fixed Bandwidth = 2.5 rad/sec

(c) $|\theta/\theta_c|_{max} = 10.98\ (1/\zeta_{sp_e}) - 10.80$



(d) $|\theta/\theta_c|_{max} = 27.53\tau + 8.191\ (1/\zeta_{sp_e}) - 11.03$

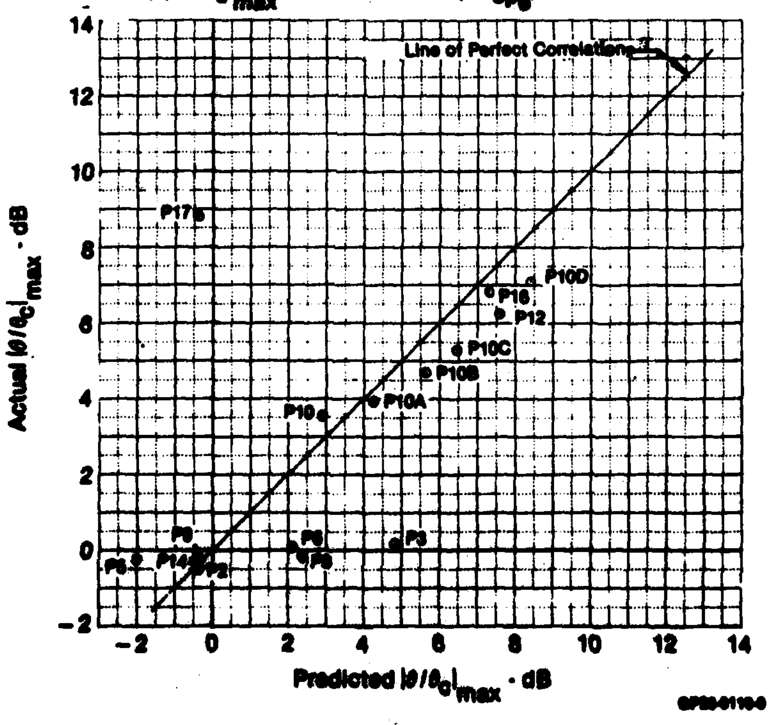


Figure F-6 (Continued). Resonance - Actual vs Predicted, Longitudinal ESP Data

L_α Fixed   Bandwidth = 2.5 rad/sec

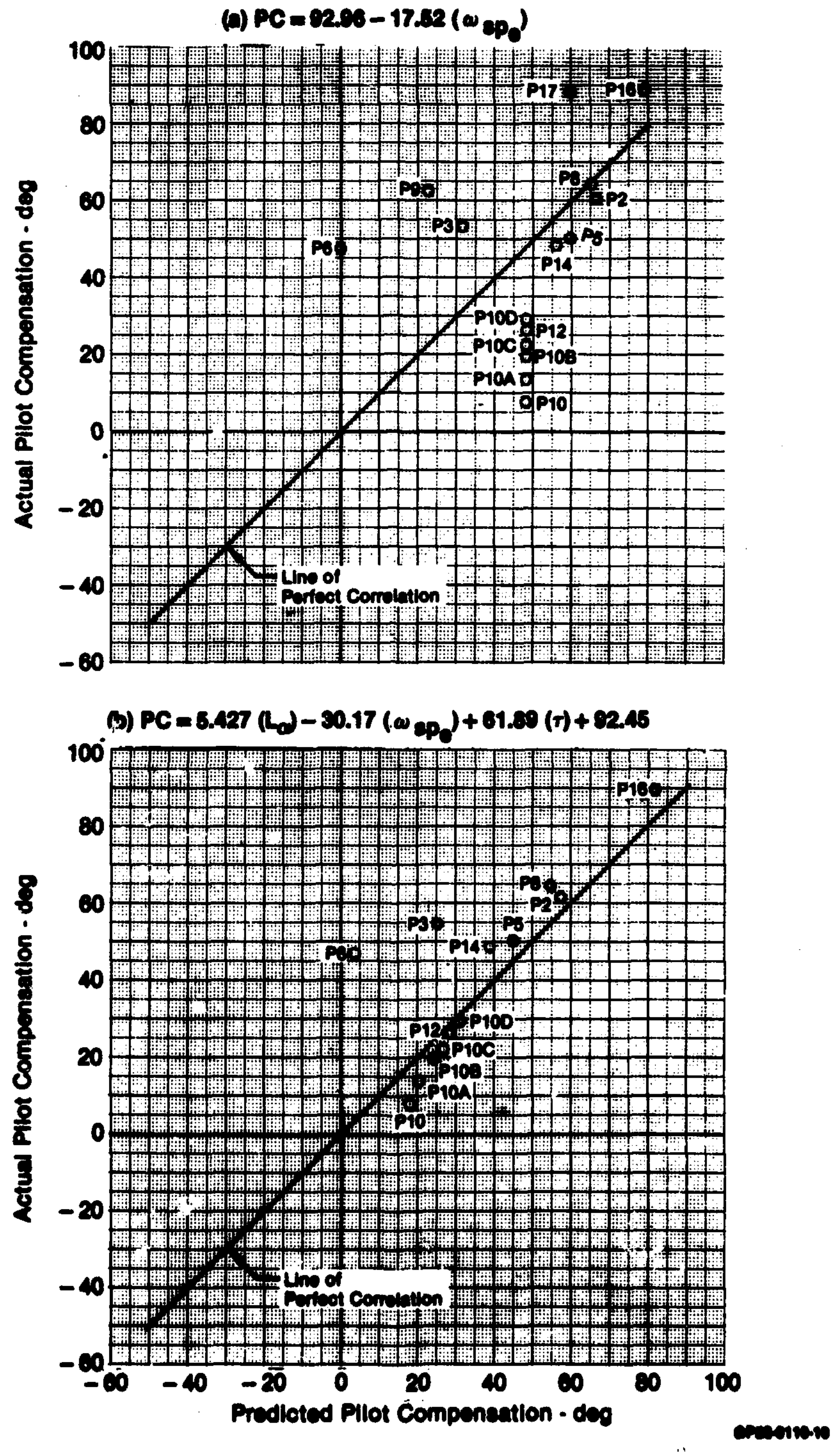


Figure F-7. Pilot Compensation - Actual vs Predicted, Longitudinal ESP Data
L_α Free Bandwidth = 2.5 rad/sec

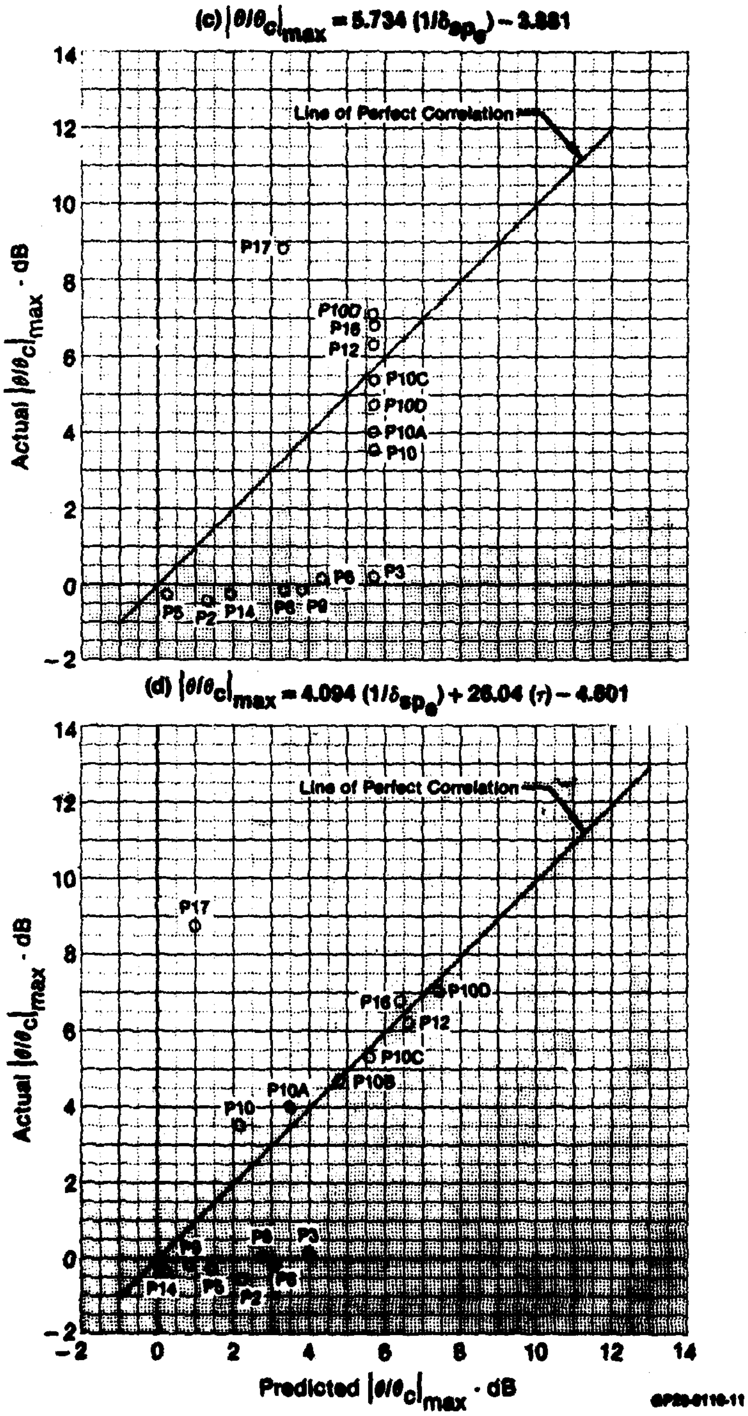


Figure F-7 (Continued). Resonance - Actual vs Predicted, Longitudinal ESP Data

L_α Free Bandwidth = 2.5 rad/sec

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